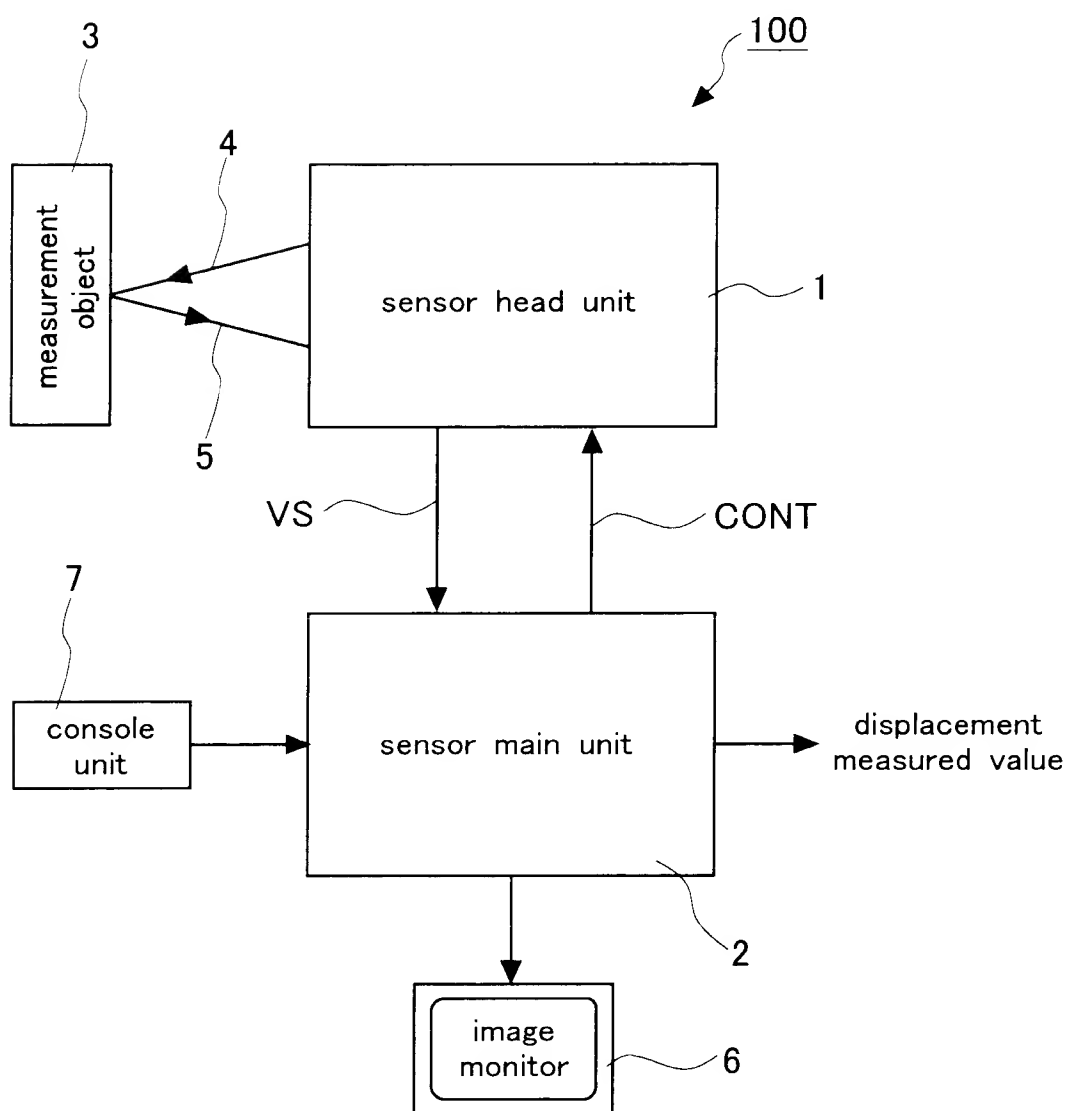


Fig. 1



An overall view of a visual displacement sensor

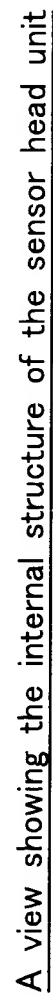
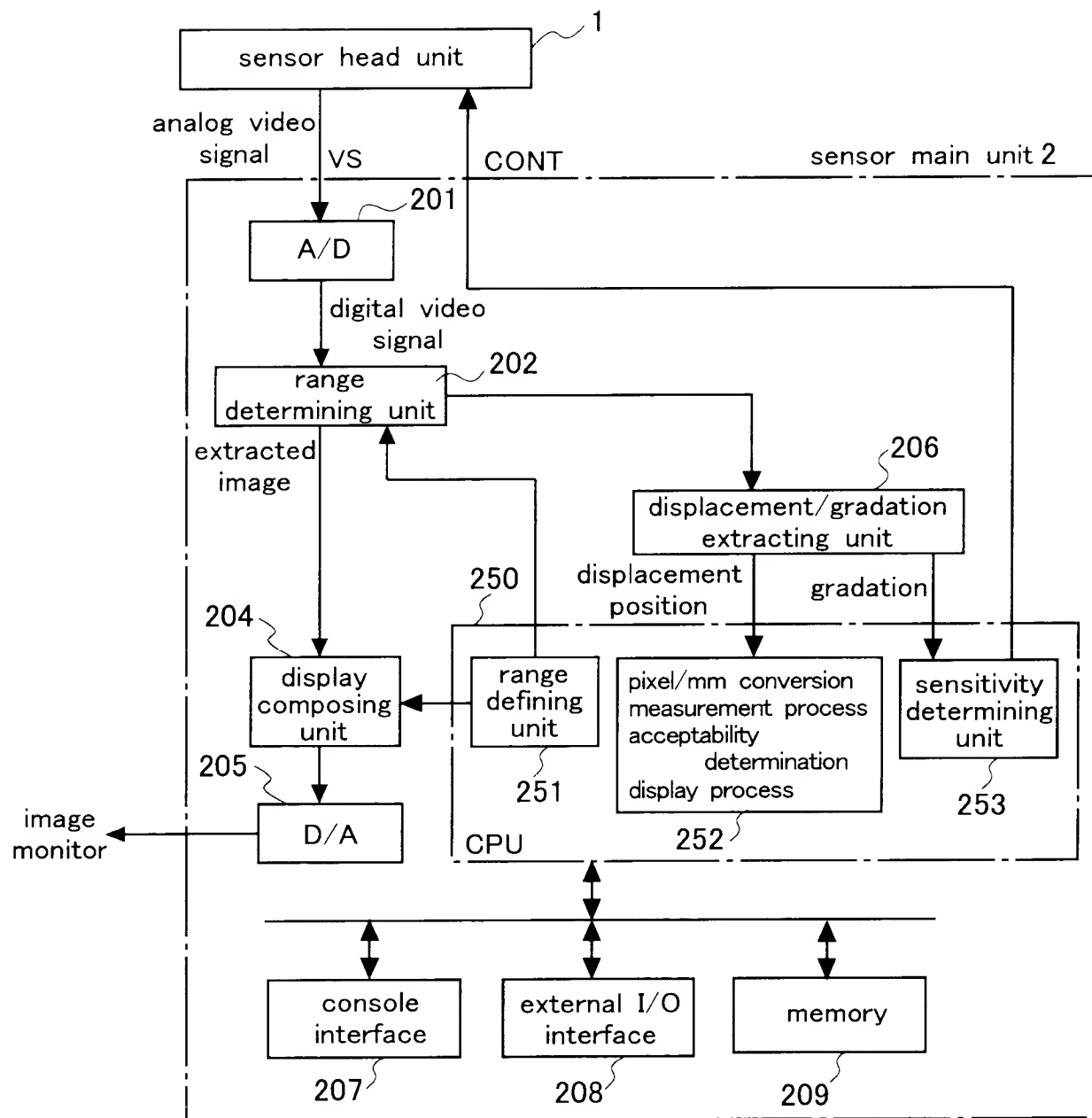
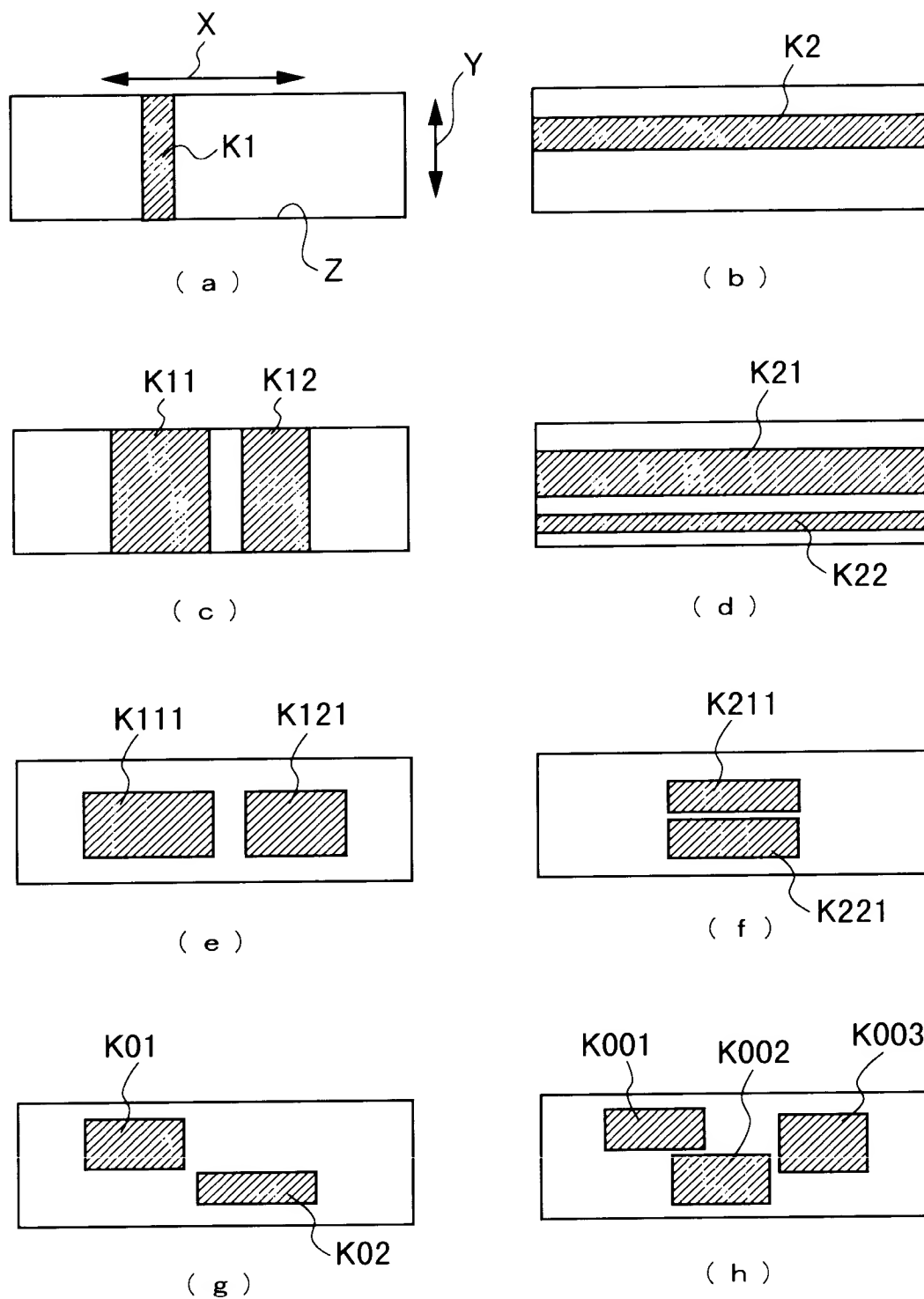


Fig. 3



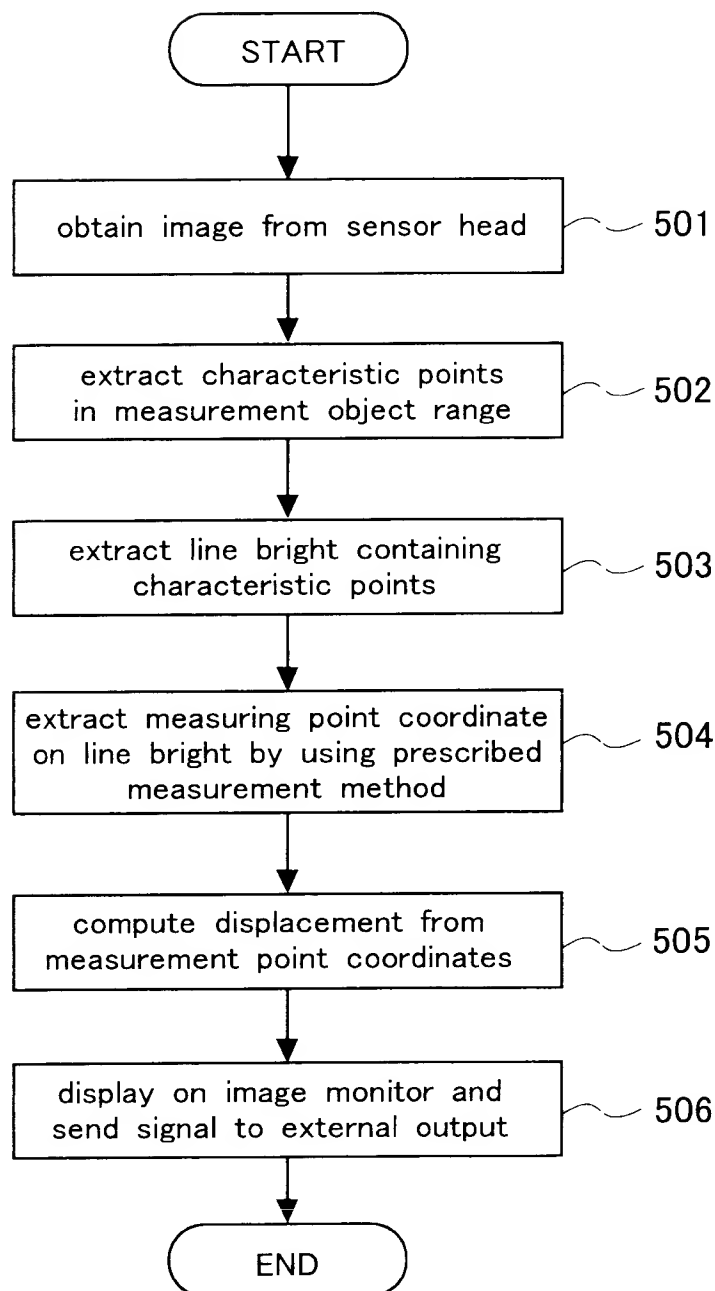
A block diagram (part 1)  
 showing the functional internal structure of the sensor main unit

Fig. 4



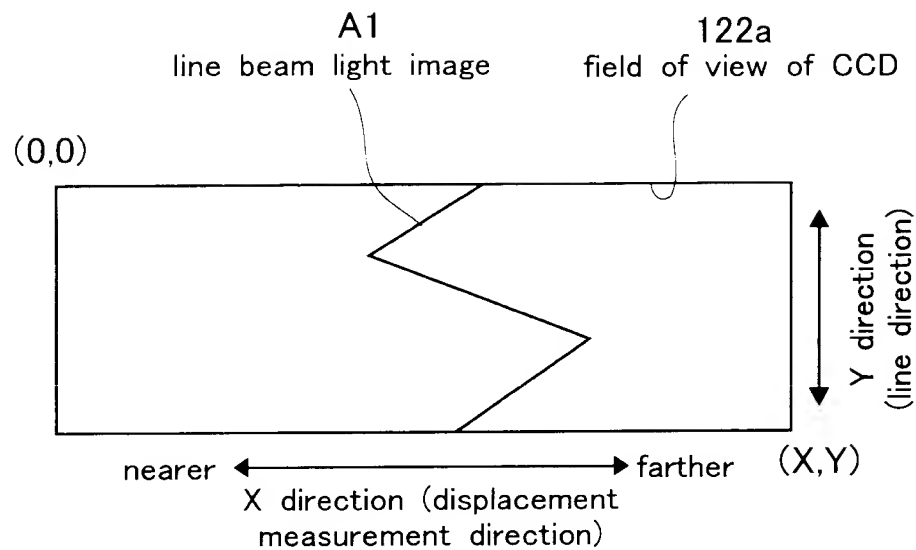
A view showing a mode of defining measurement object ranges

Fig. 5



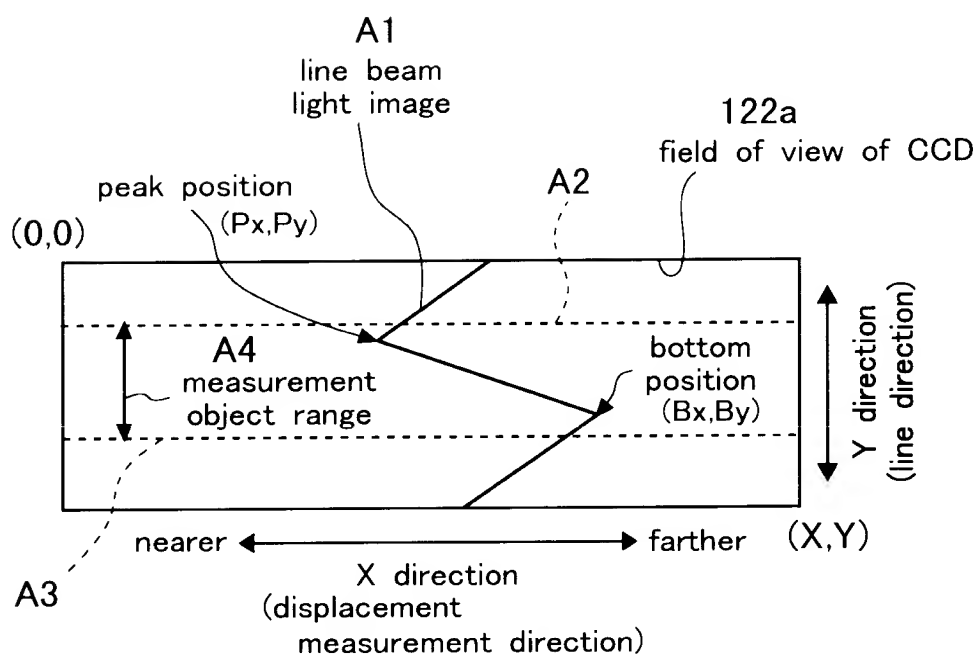
A general flow chart schematically illustrating the operation of the displacement measurement by the sensor main unit

Fig. 6



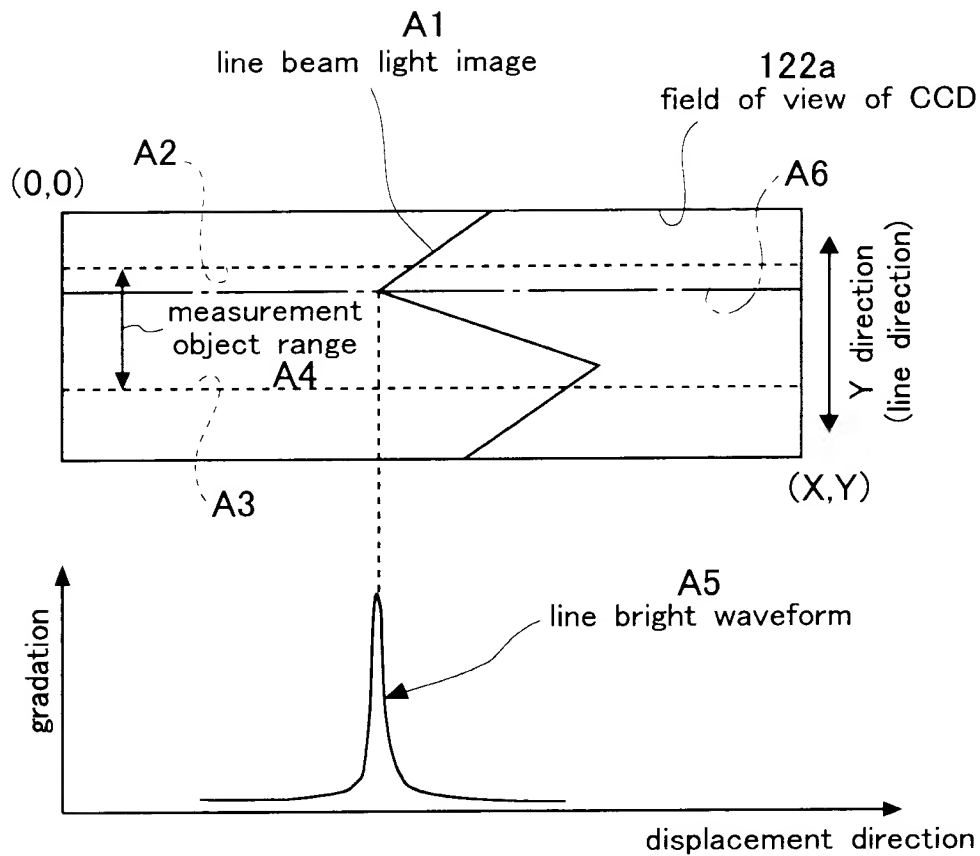
A view illustrating an image  
captured by the CCD incorporated in the sensor head unit

Fig. 7



A view illustrating the process of  
extracting measurement points in a measurement object range

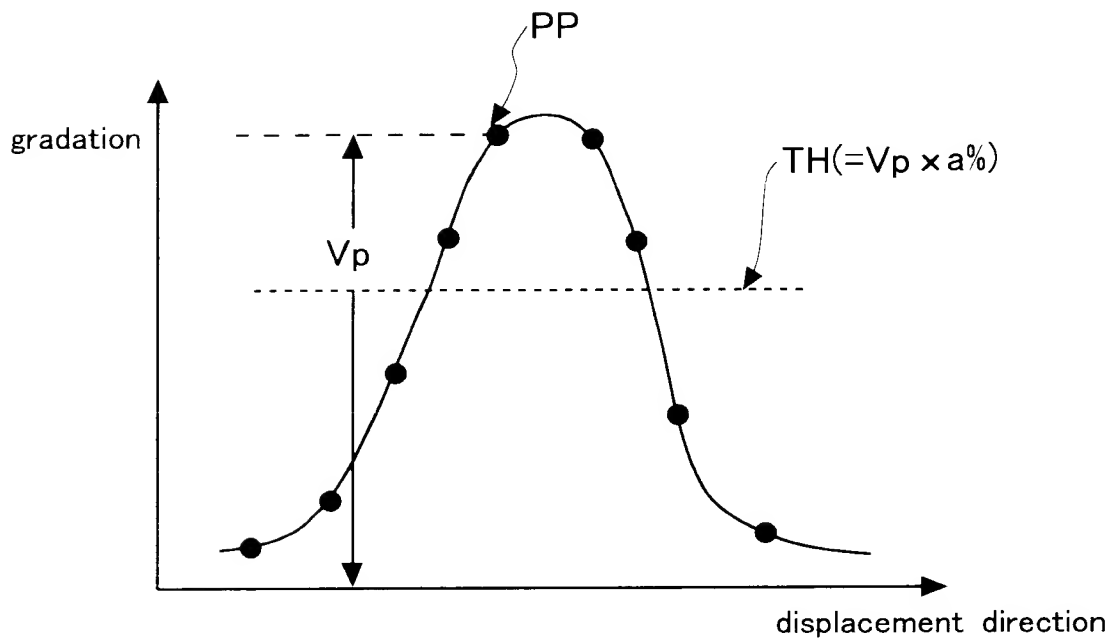
Fig. 8



A view illustrating the relationship  
between the line bright waveform and the image captured by the CCD

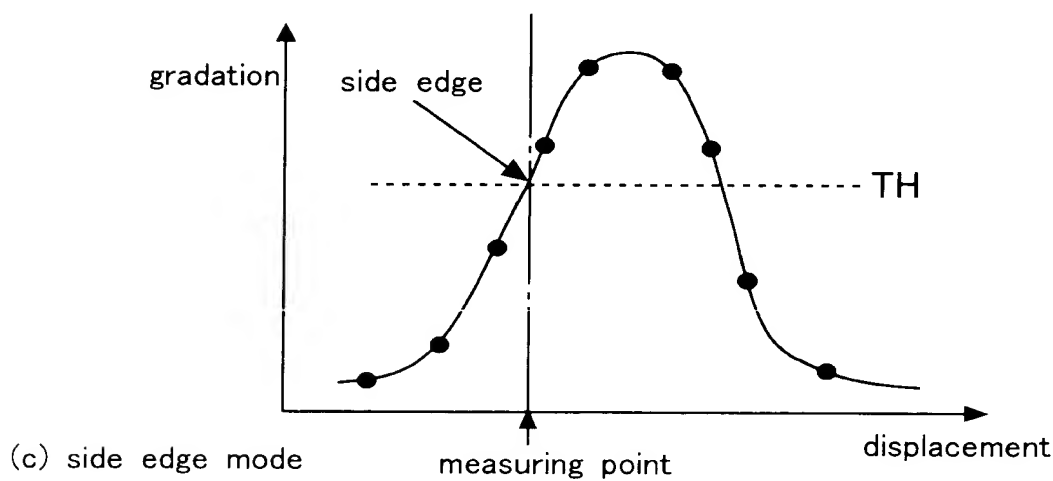
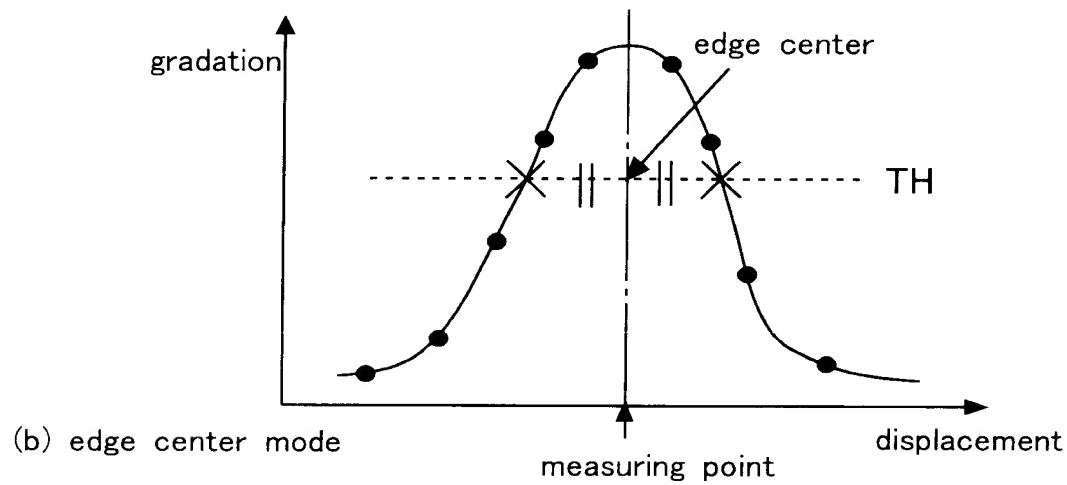
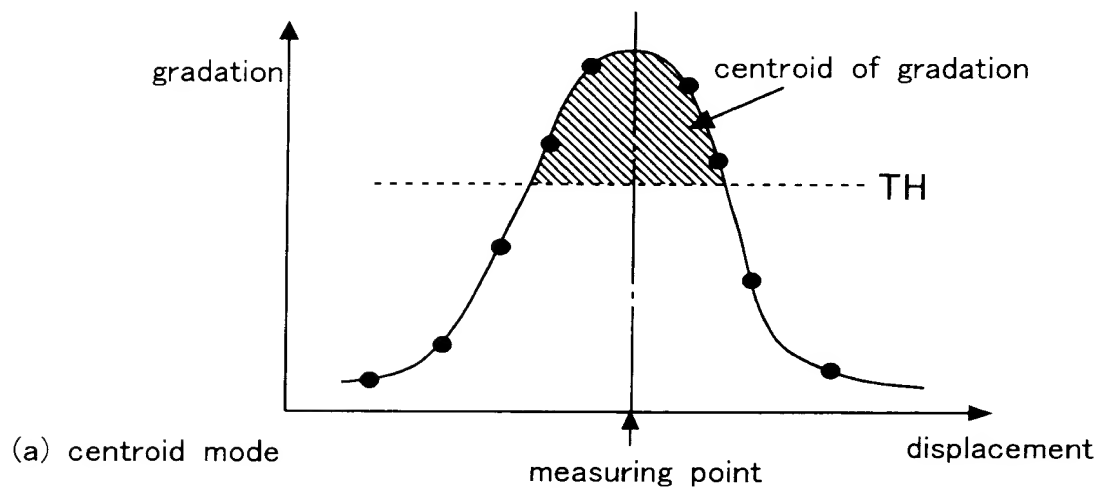


Fig. 9



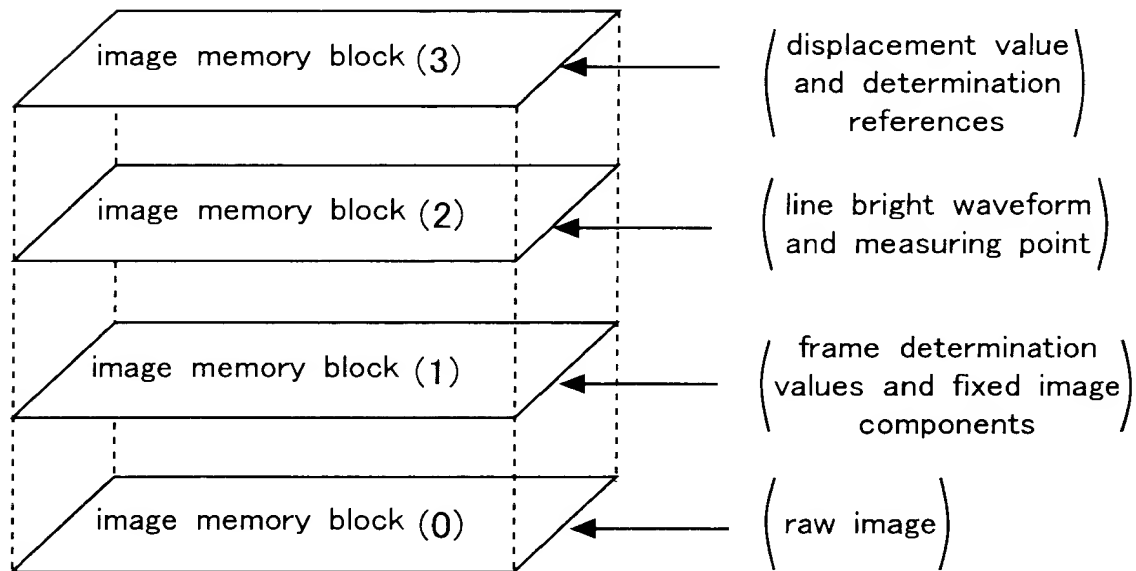
An illustrative view showing the process of determining the threshold value

Fig. 10



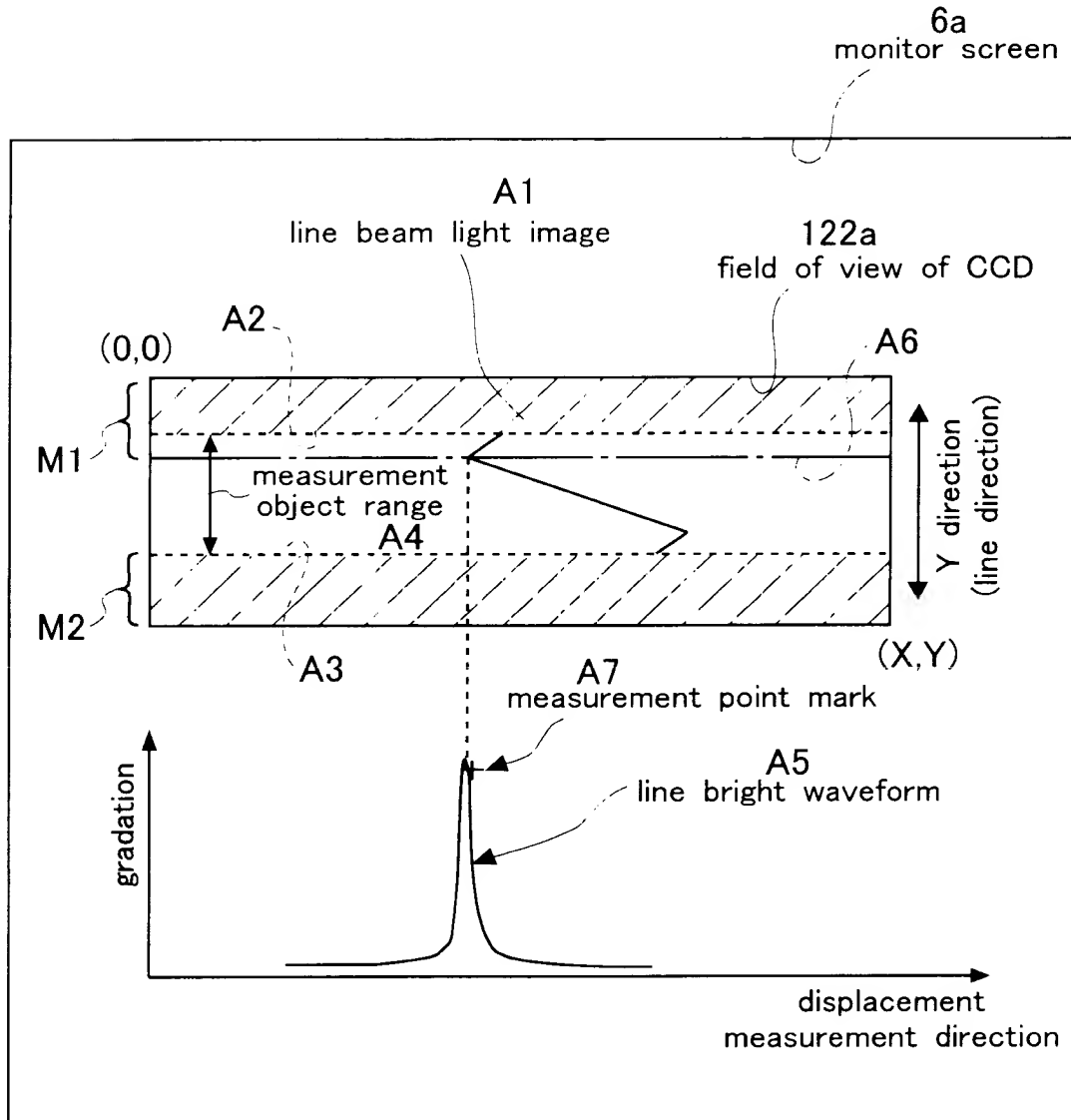
An illustrative view showing the process  
of extracting the measuring point coordinate

*Fig. 11*



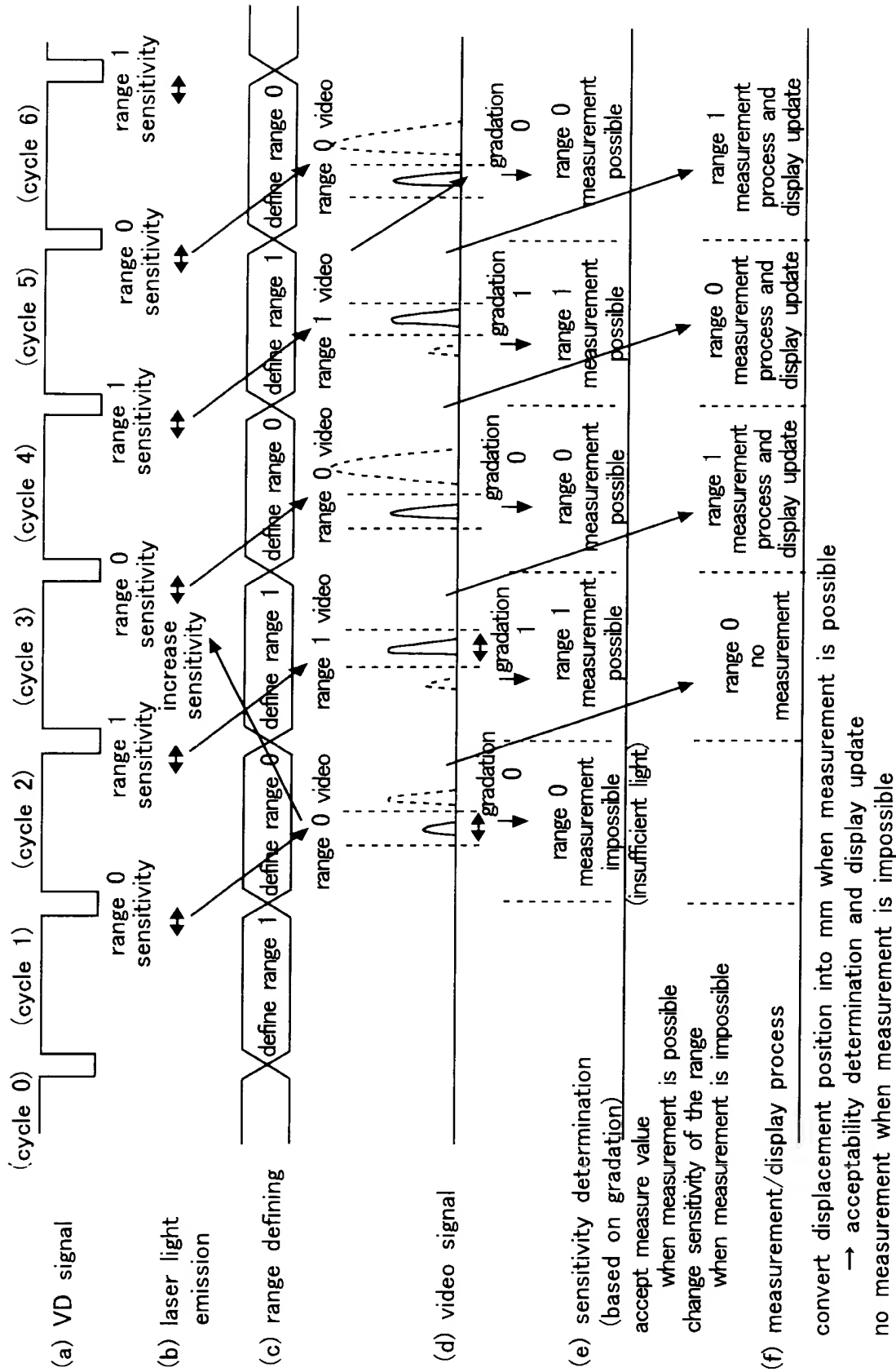
An illustrative view showing the process of generating the monitor display

*Fig. 12*



A view showing an exemplary monitor display showing the relationship between the image captured by the CCD and line bright waveform

Fig.13



A time chart showing the gradation adjustment process for each range

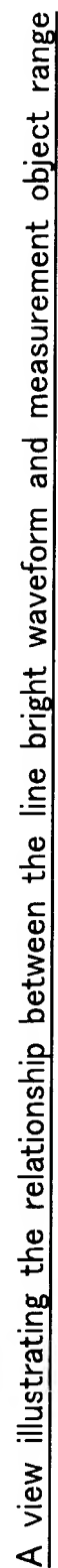
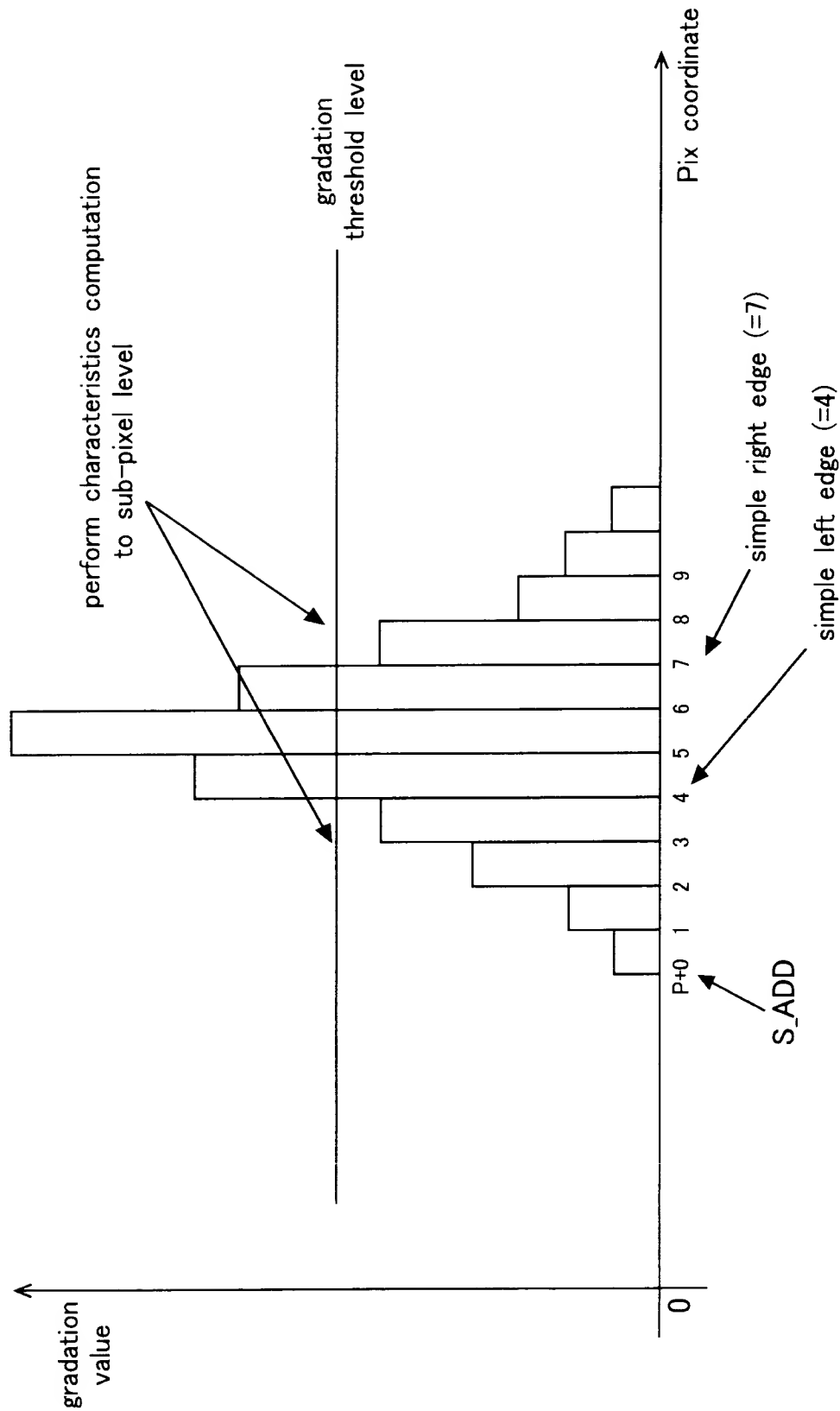
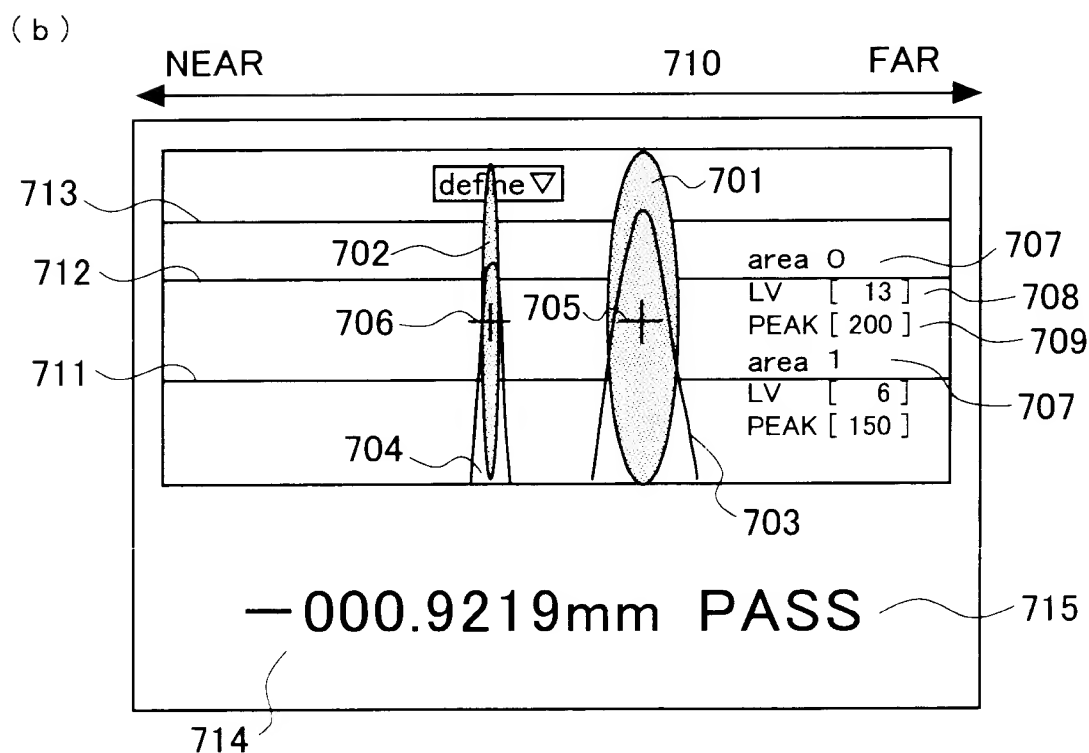
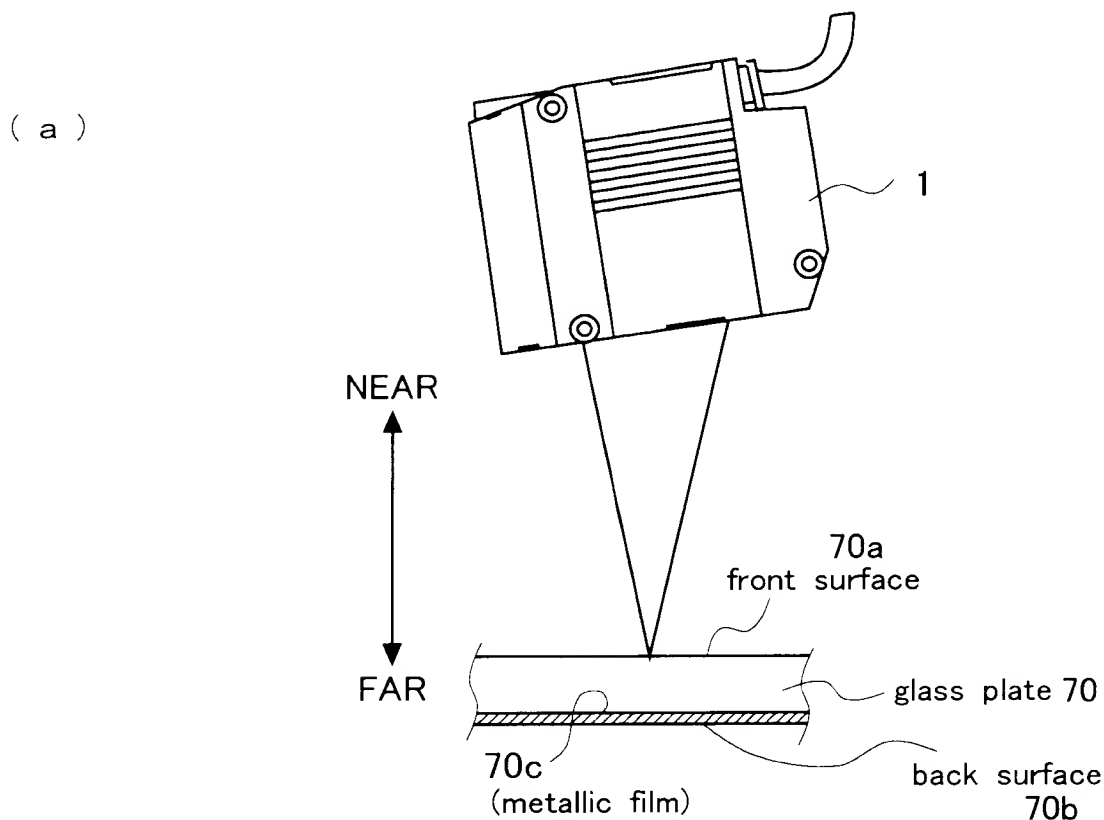
[illegible]

Fig. 15



A view illustrating the characteristic computation for determining measurement point coordinates

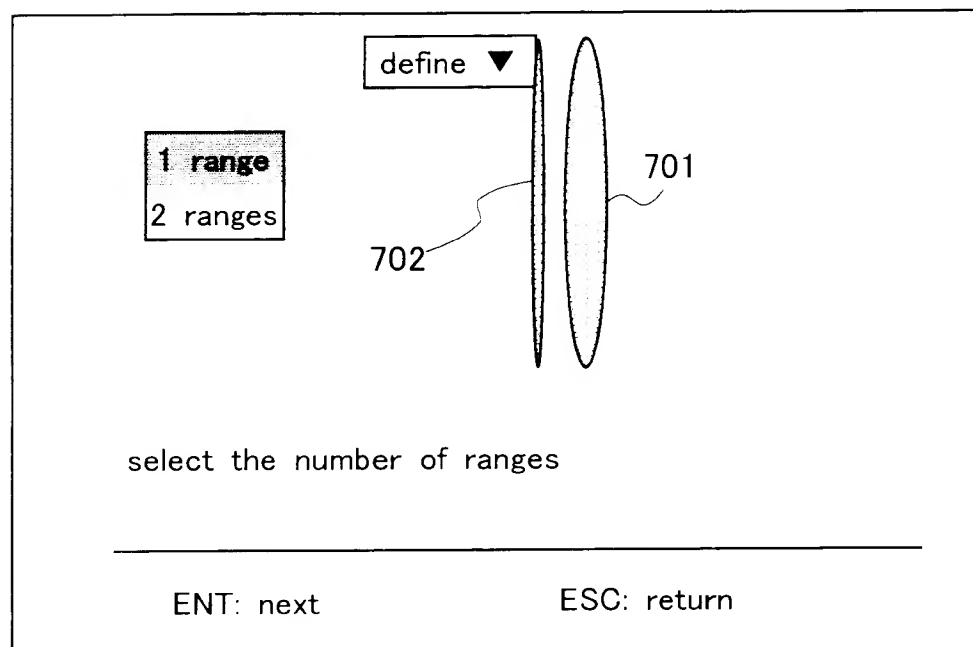
Fig.16



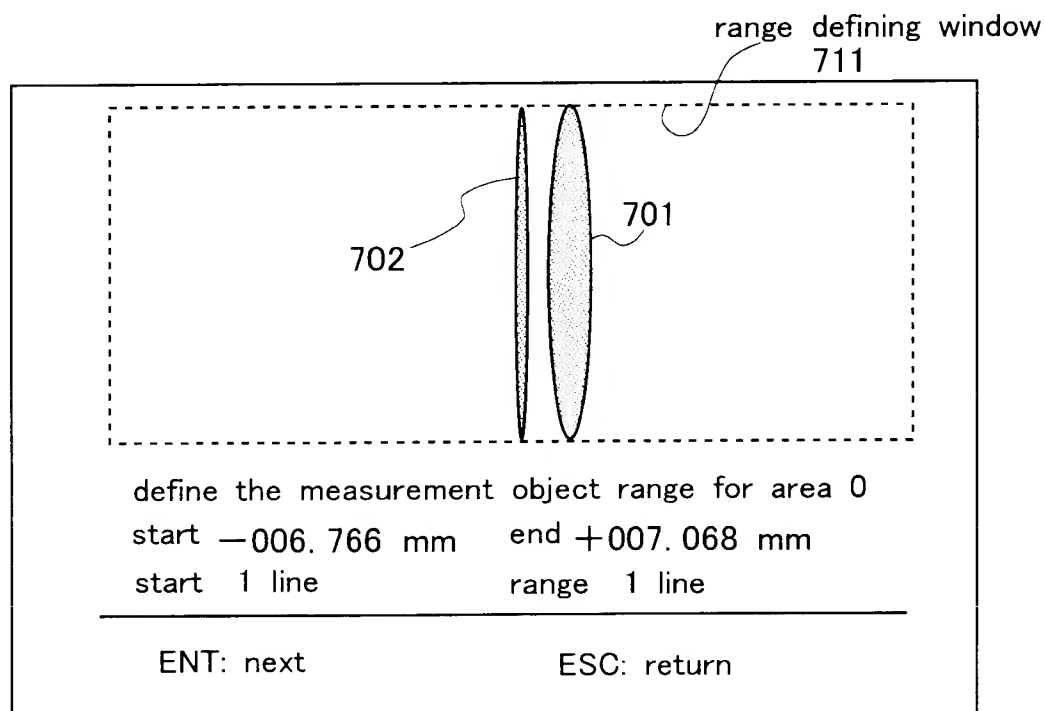
a view showing a conventional measurement result



Fig.17



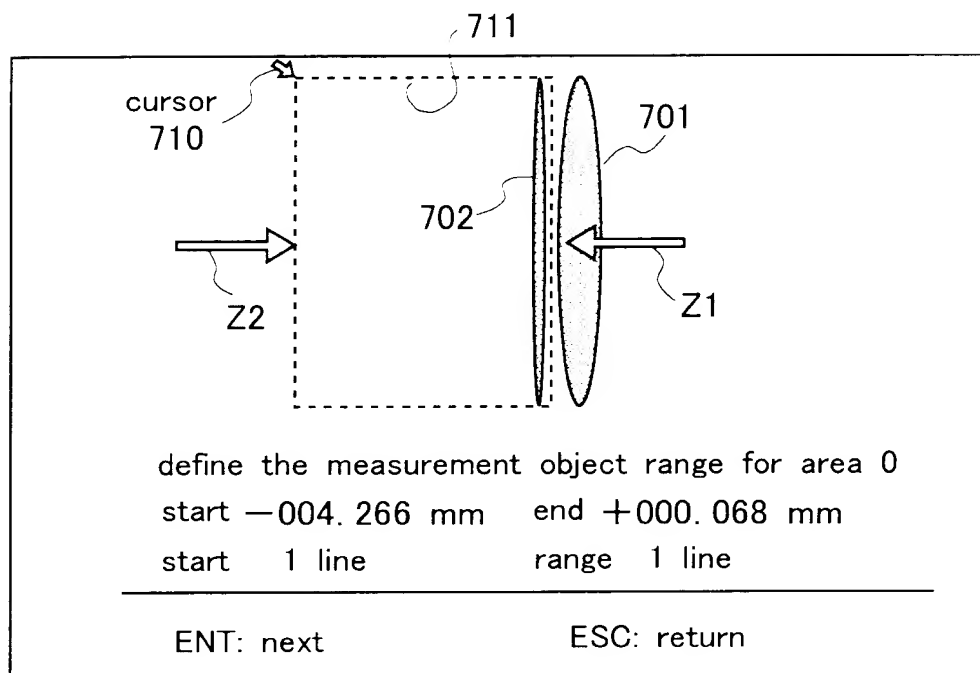
(a) selecting the number of ranges to be defined



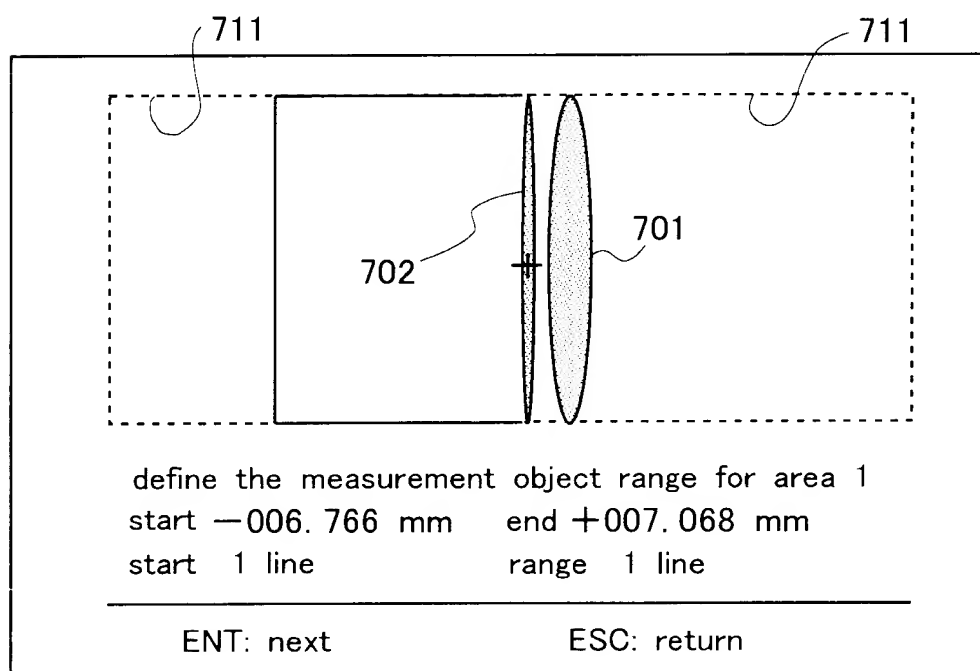
(b) defining measurement object range 0

A view illustrating the monitor screen when defining regions (part 1)

Fig. 18



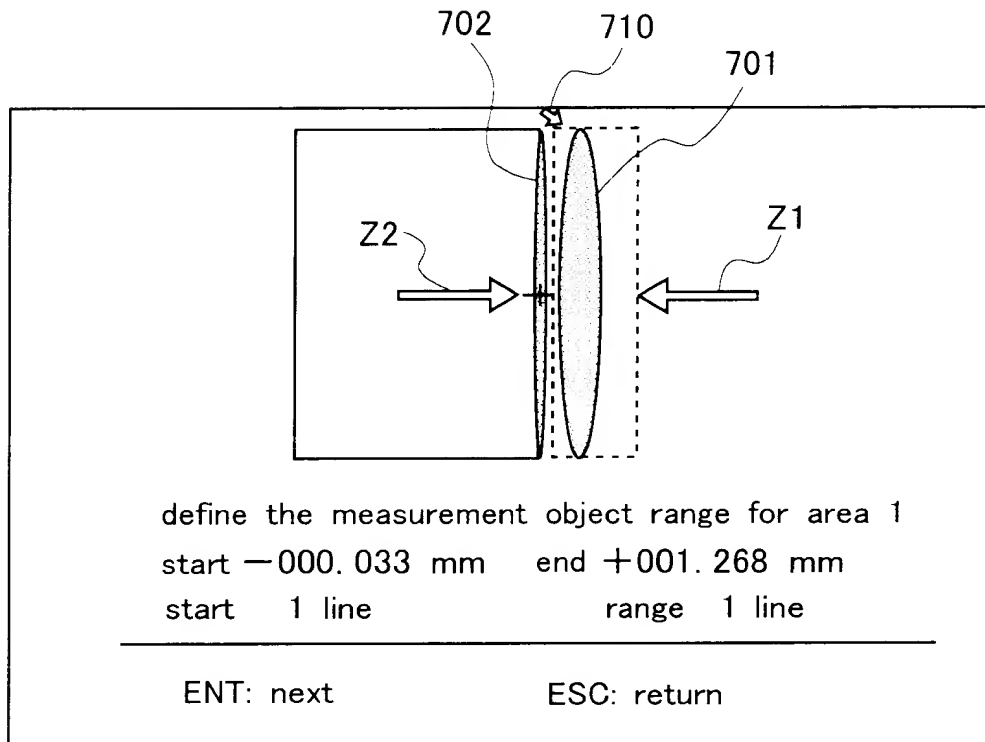
(a) defining measurement object range 0



(b) complete the defining of measurement object range 0  
(acquire a relative reference position)

A view illustrating the monitor screen when defining regions (part 2)

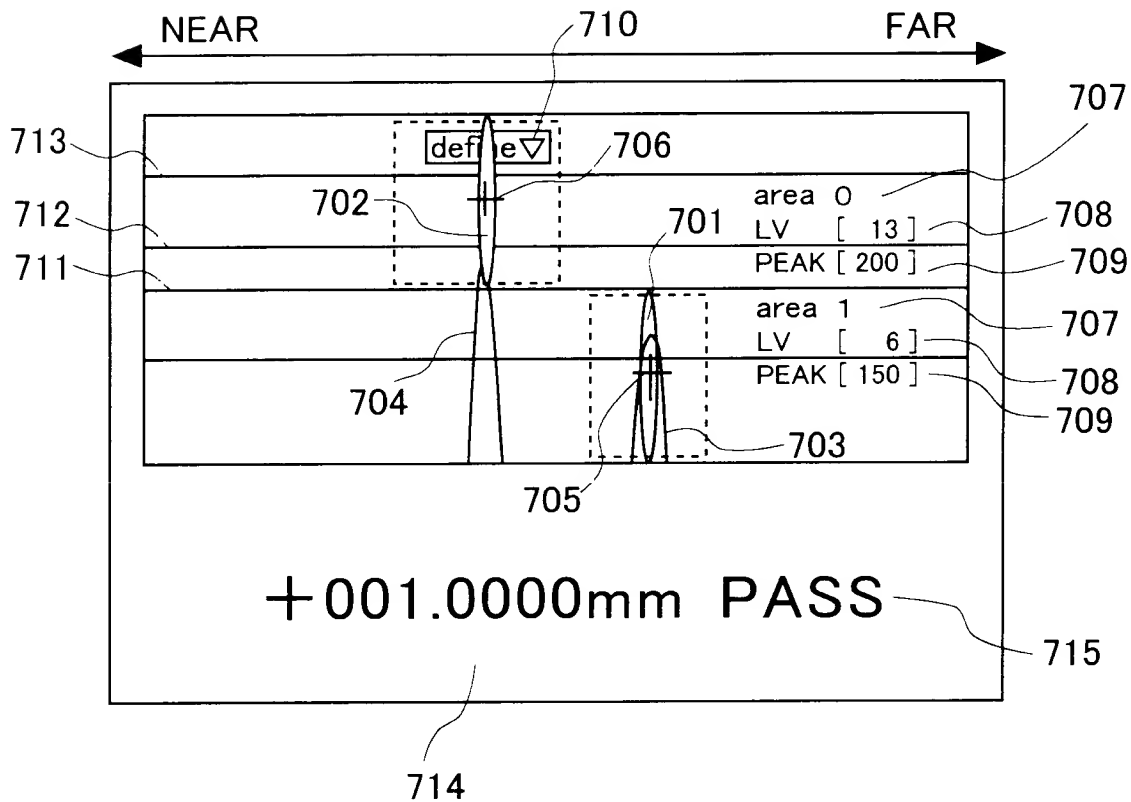
Fig. 19



defining measurement object range 1  
→ select only the back surface  
for the measurement object range

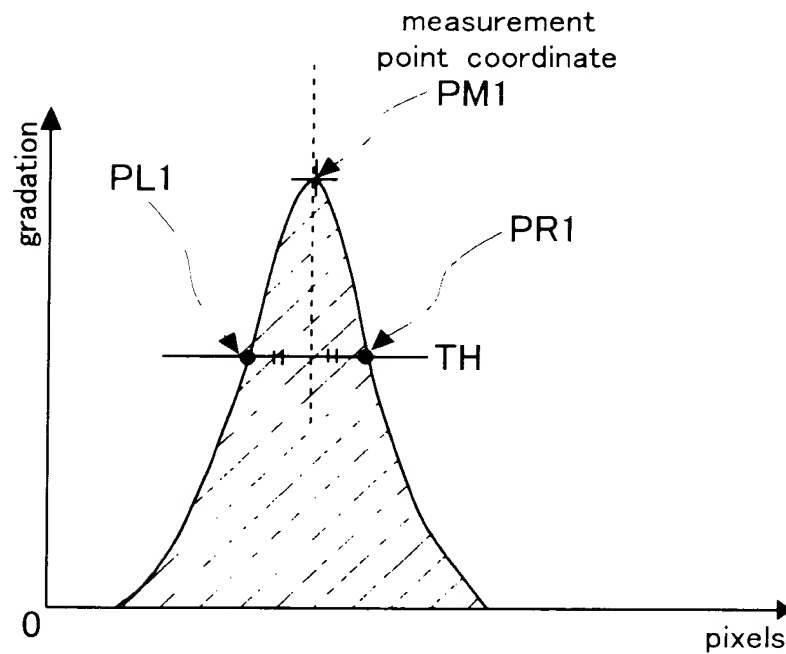
A view illustrating the monitor screen when defining regions (part 3)

Fig.20

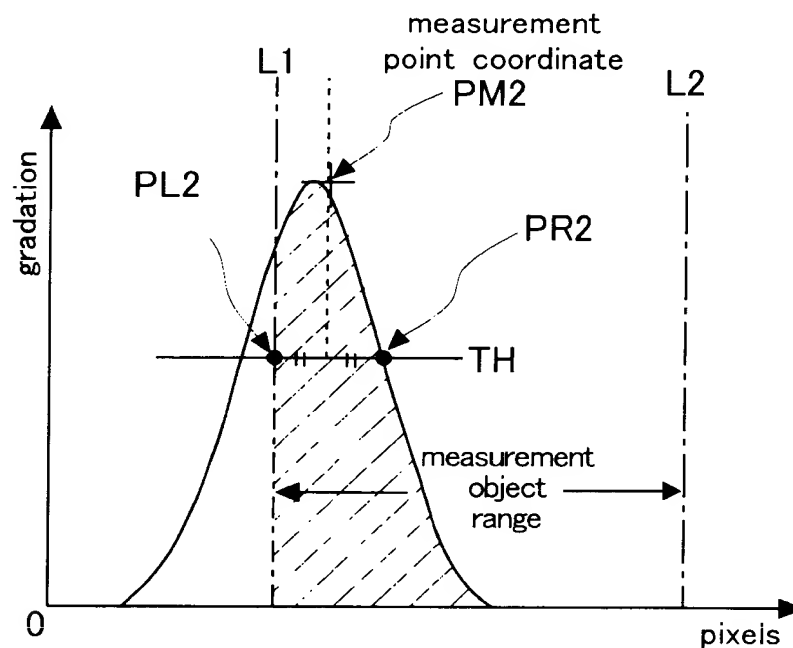


A view illustrating the monitor screen at the time of measurement after two measurement object ranges are defined

Fig.21



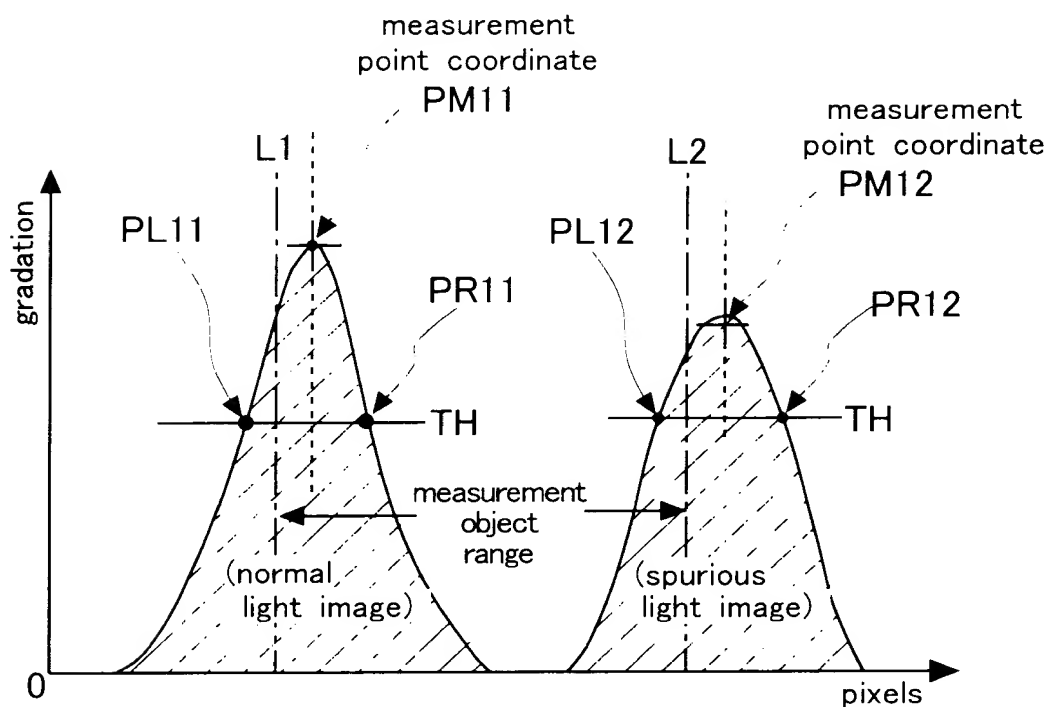
(a) measurement point coordinate extracted from the input image



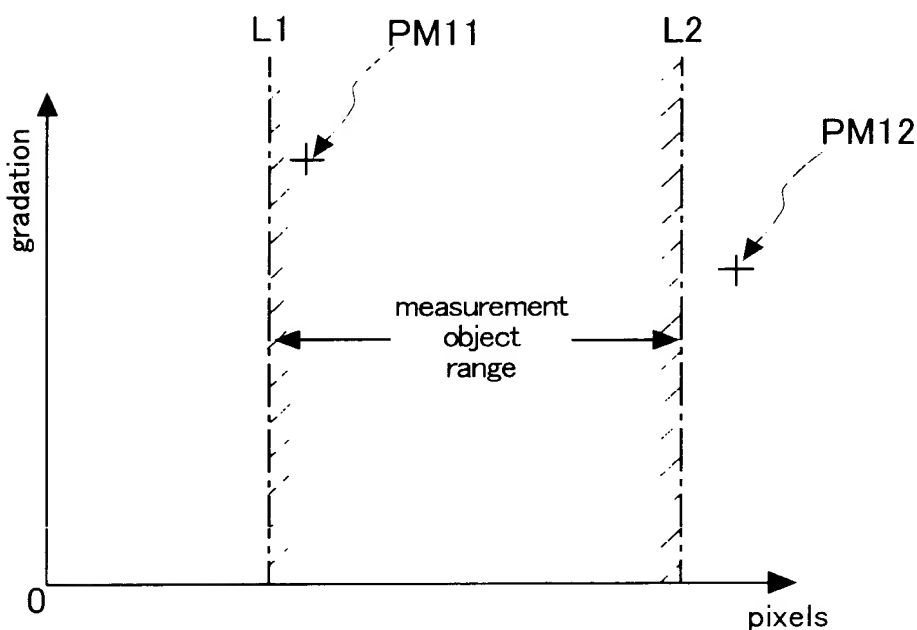
(b) measurement point coordinate extracted from the masked image

A view illustrating the problem with the process  
of extracting a measurement point coordinate using a masked image

Fig.22



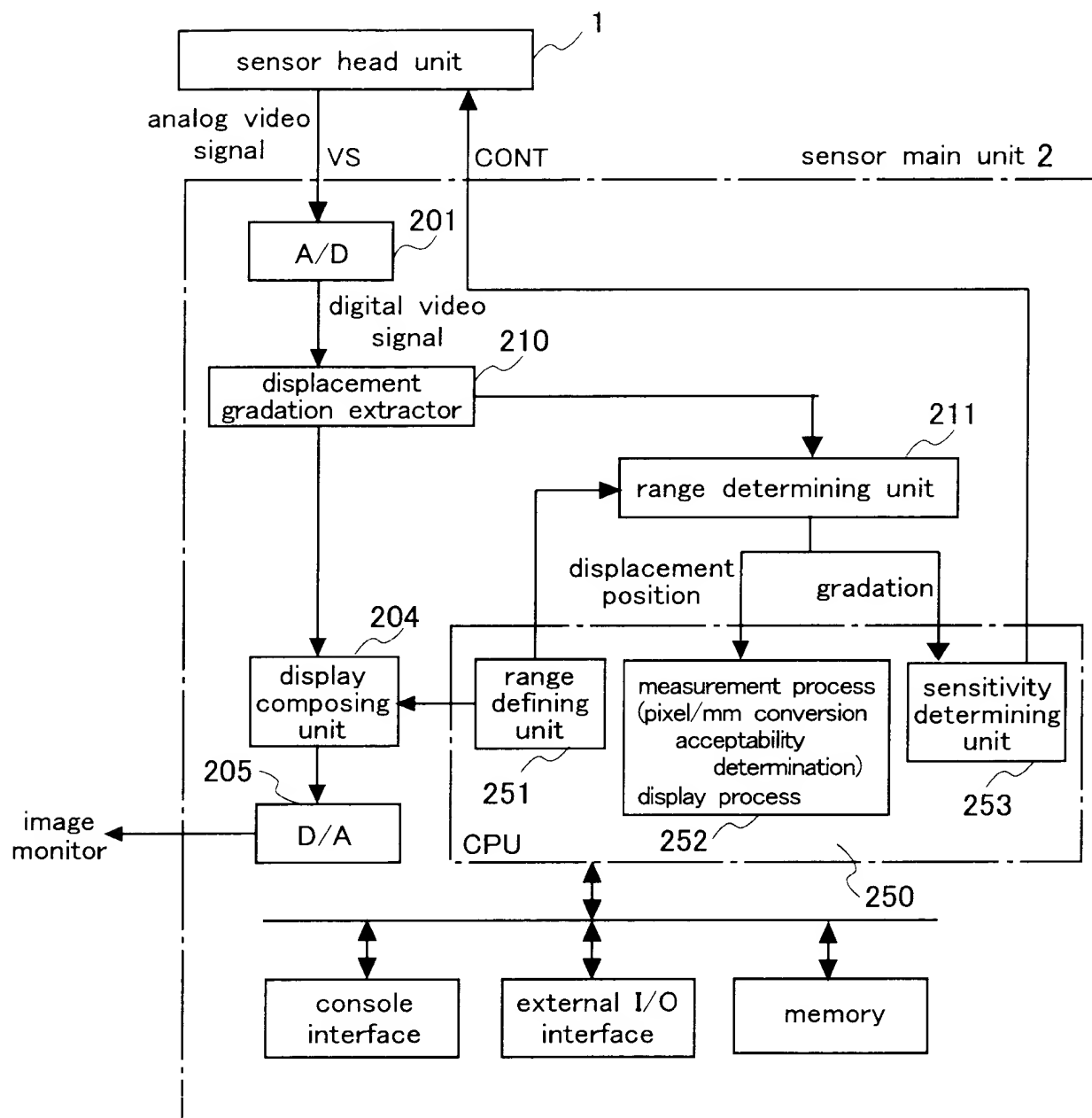
(a) provisional decision of measurement point coordinates



(b) formal decision of measurement point coordinates

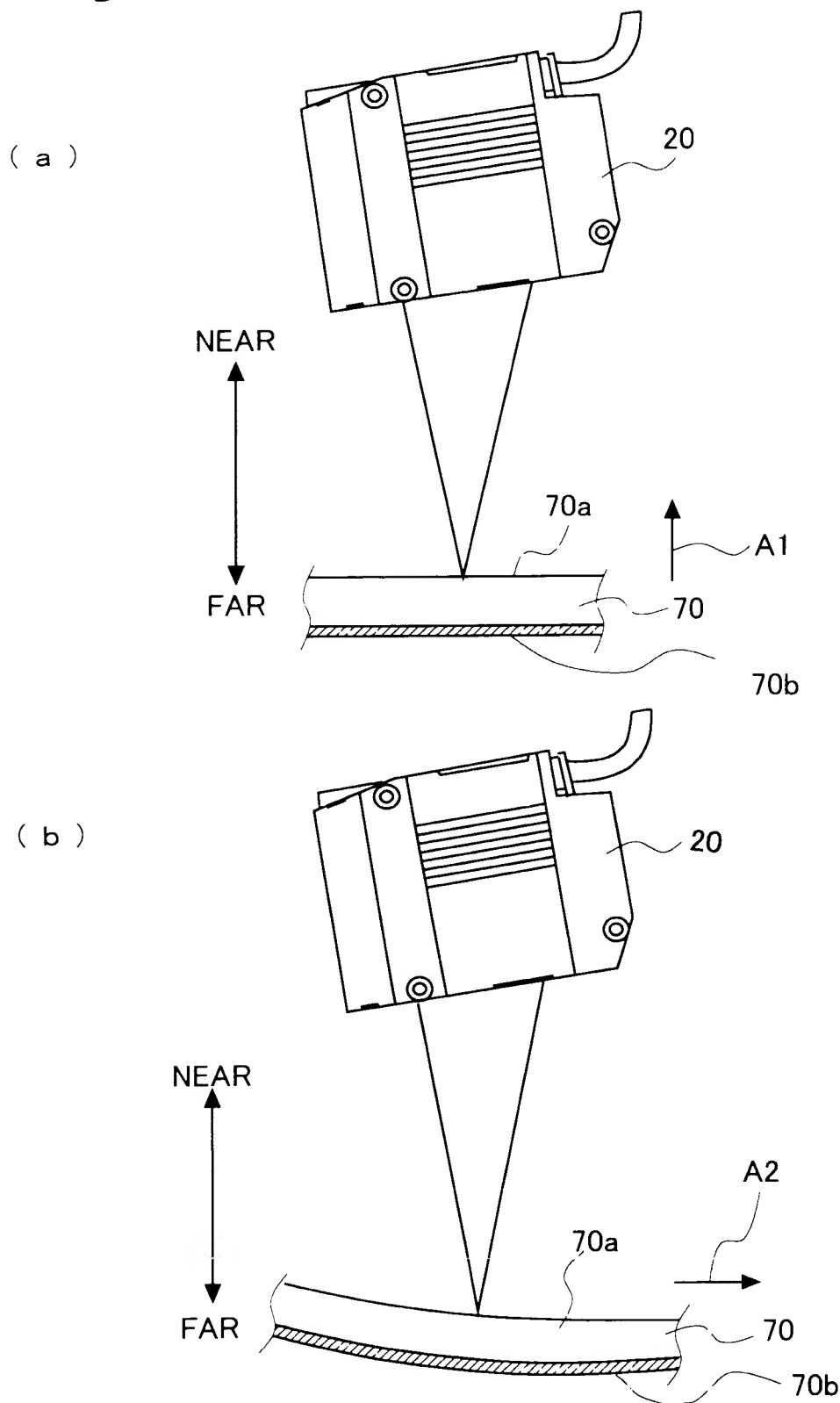
A view illustrating the second embodiment of the process  
of extracting a measurement point coordinate using a masked image

Fig.23



A block diagram (part 2)  
 showing the functional internal structure of the sensor main unit

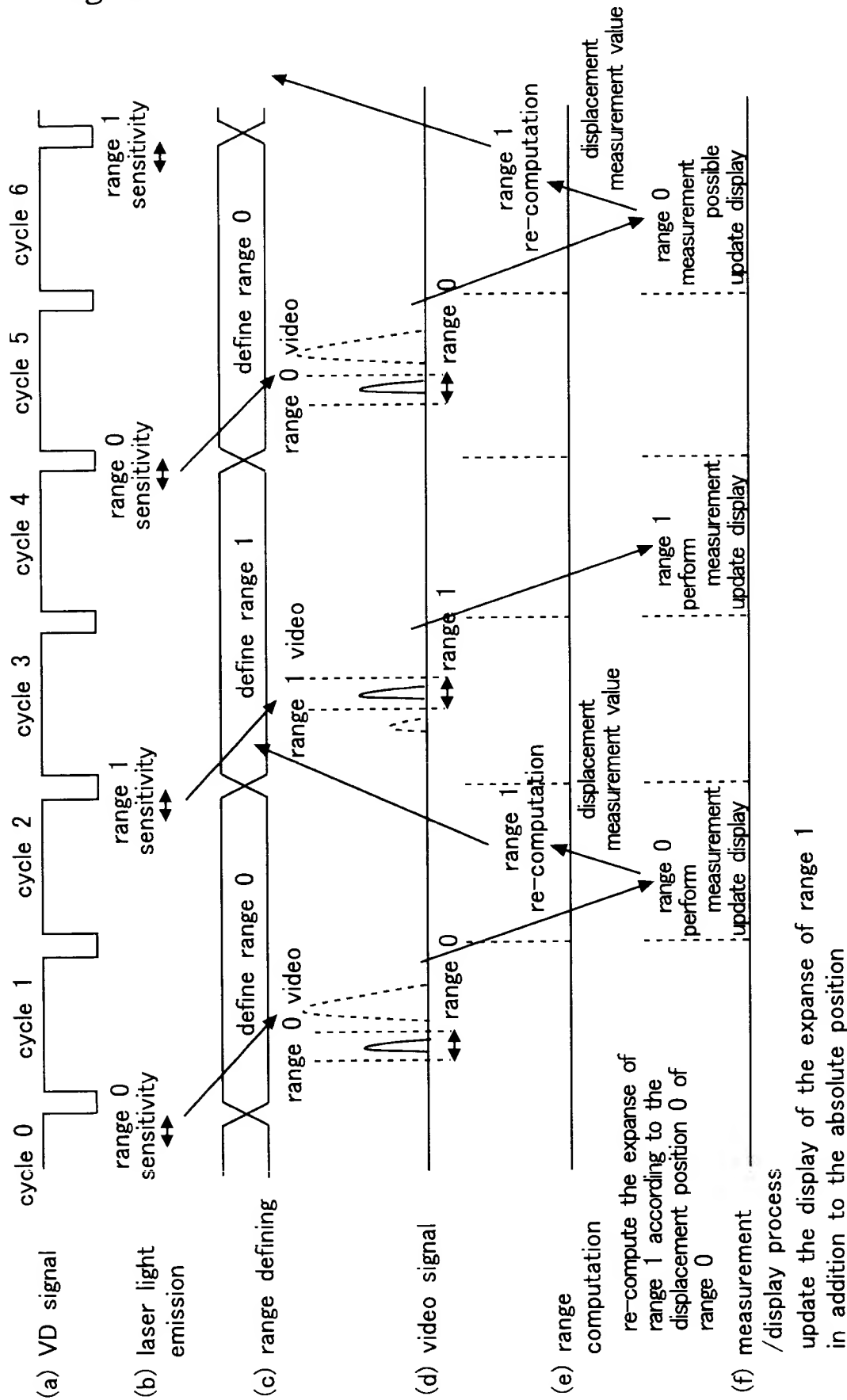
Fig.24



A view showing a mode of vertical changes in a measurement point

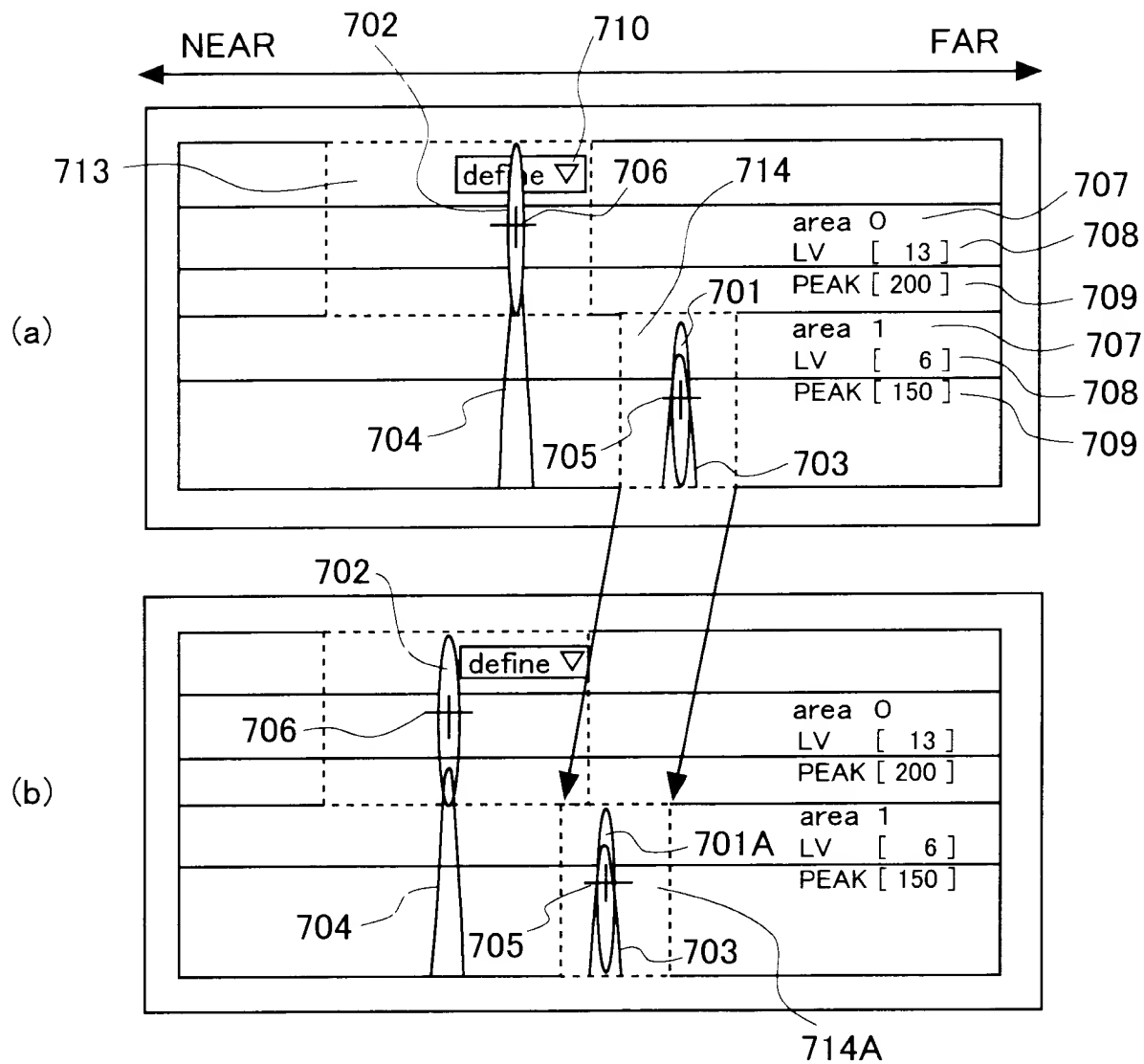


Fig.25



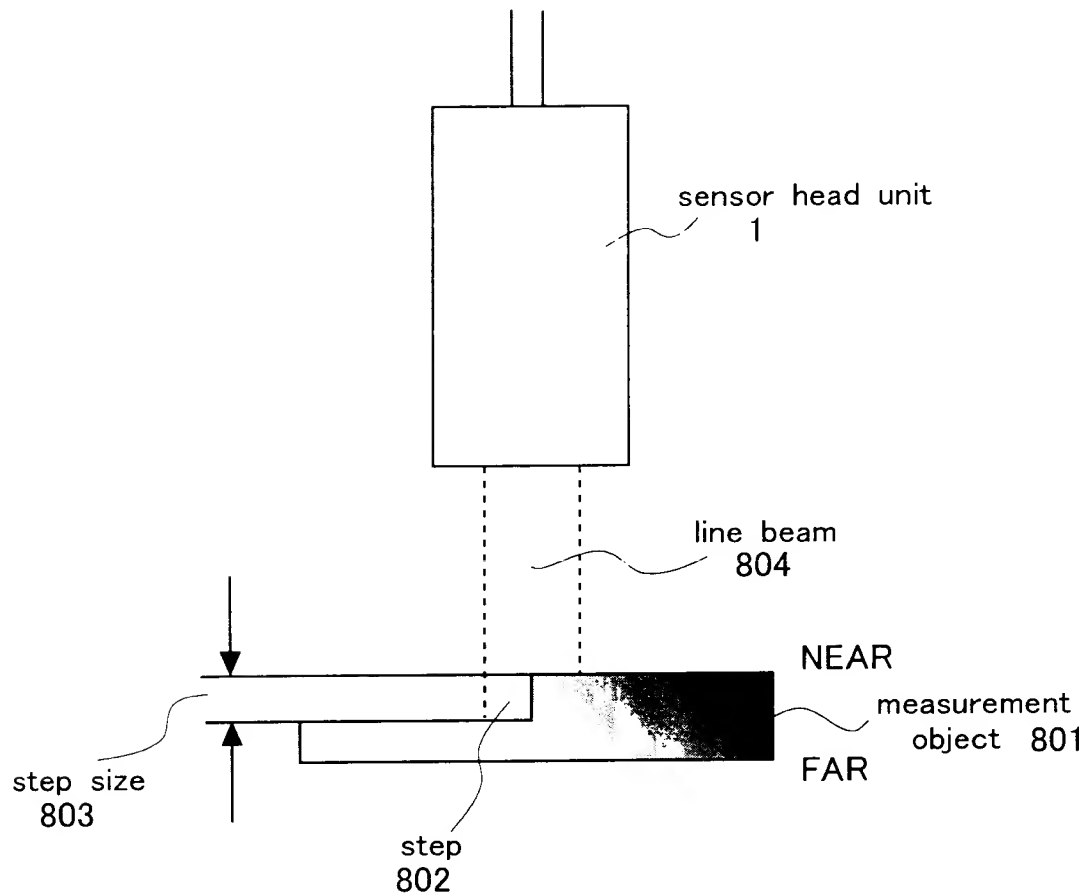
A time chart showing the process of tracking defined regions to the vertical change in the measurement point

Fig.26



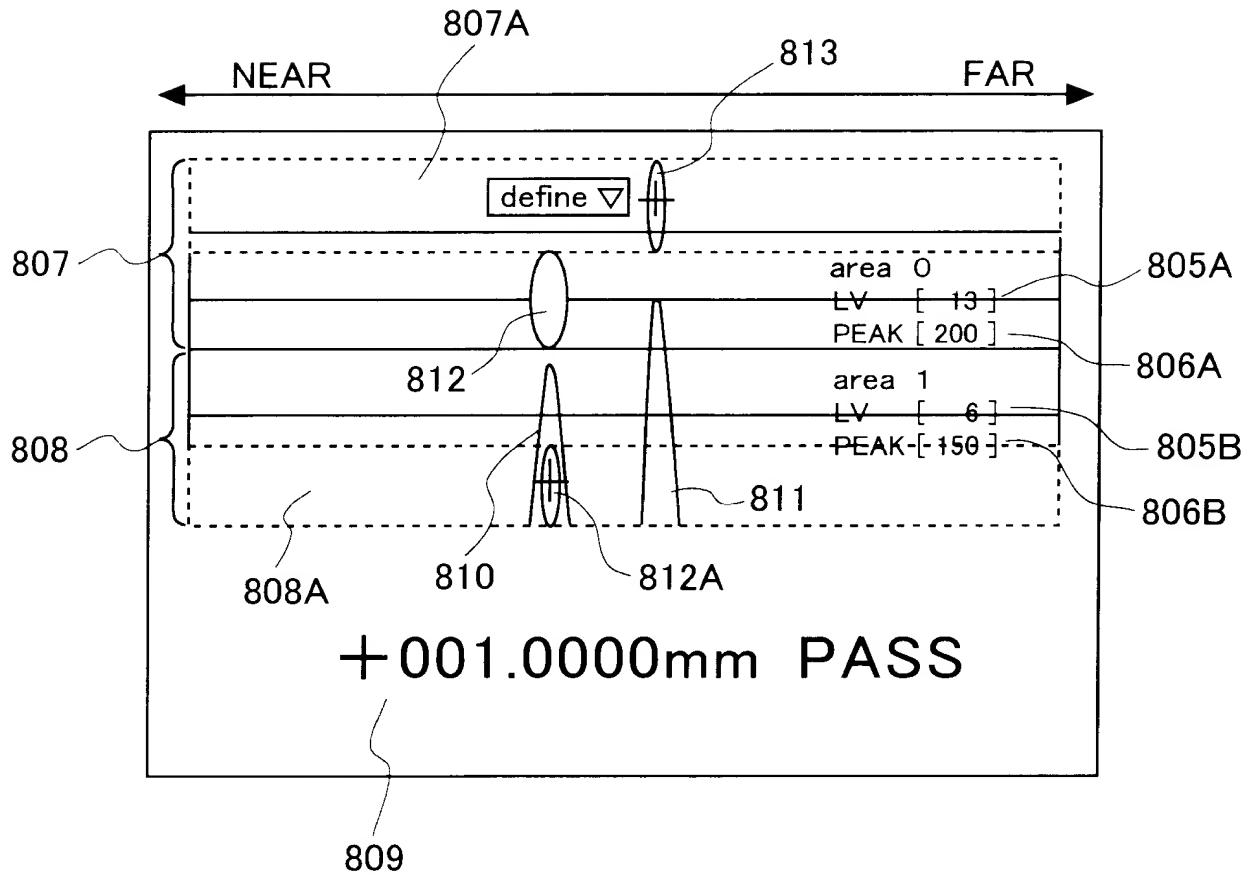
A view showing the monitor screen  
before and after the vertical change in the measurement point

Fig.27



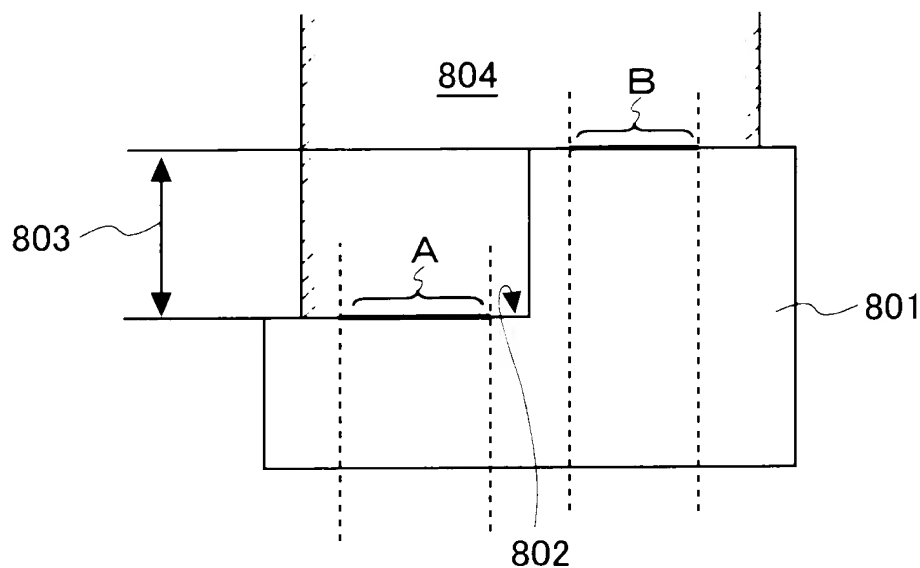
A view illustrating the positional relationship  
between the sensor and measurement object when measuring a step

Fig.28

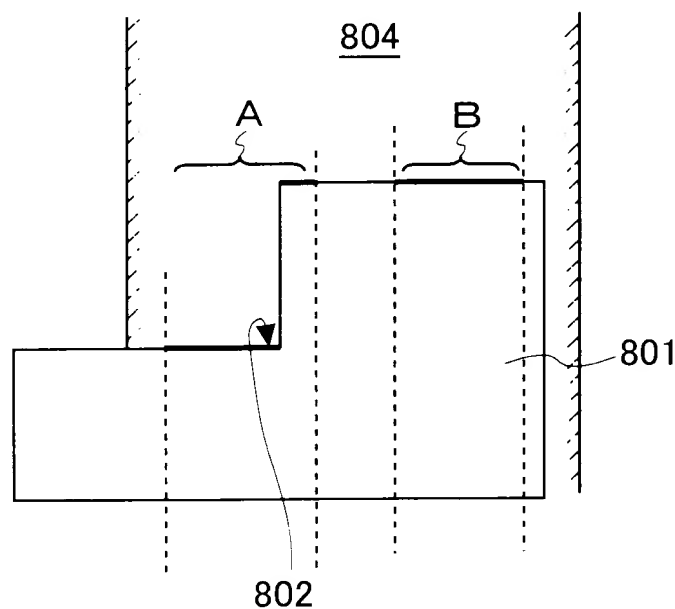


A view showing the monitor screen for the measurement of a step

Fig.29



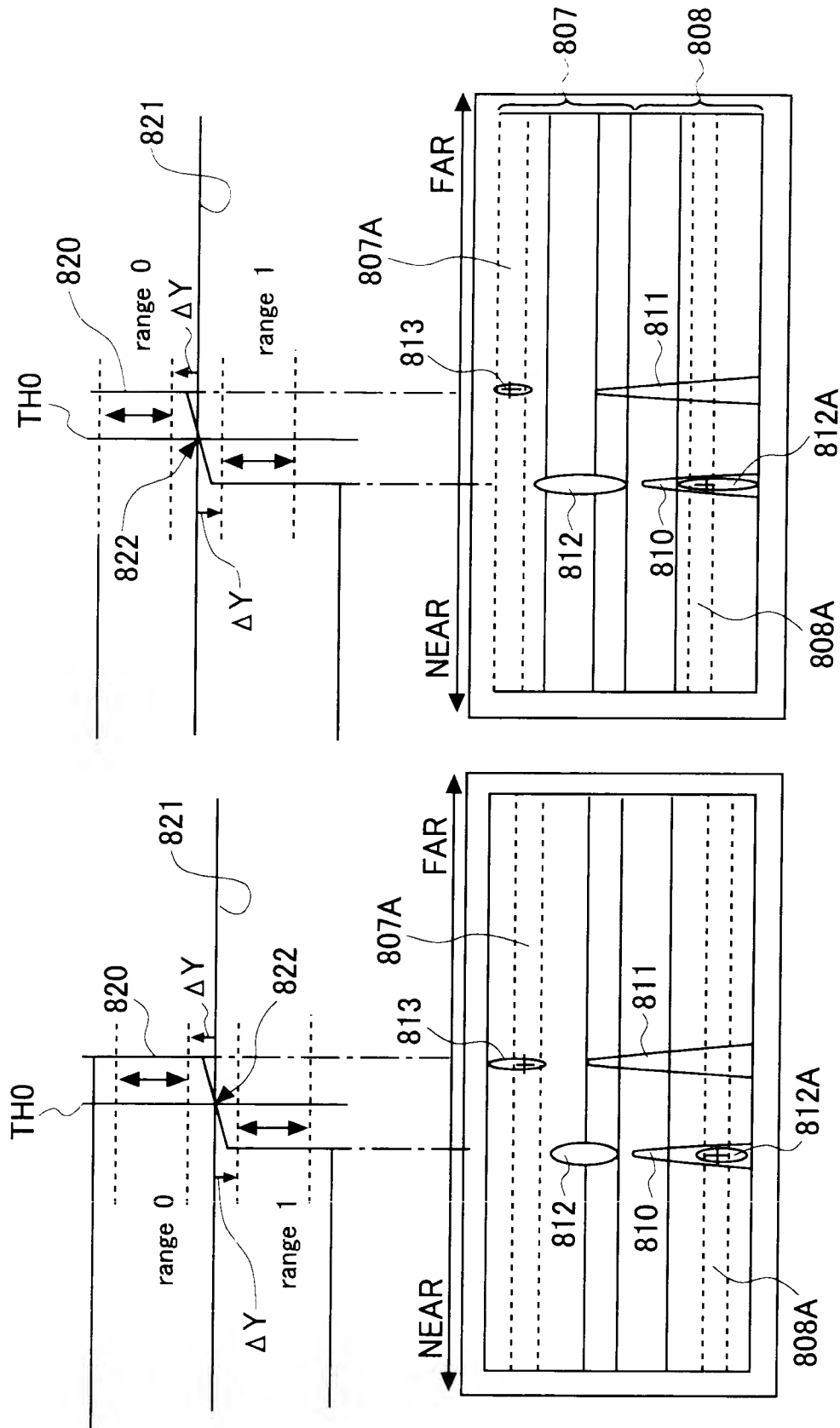
(a) when the measurement object is at the reference position



(b) when the measurement object has shifted laterally

A view illustrating the problem associated with the lateral shifting of the measurement object when measuring a step

Fig.30

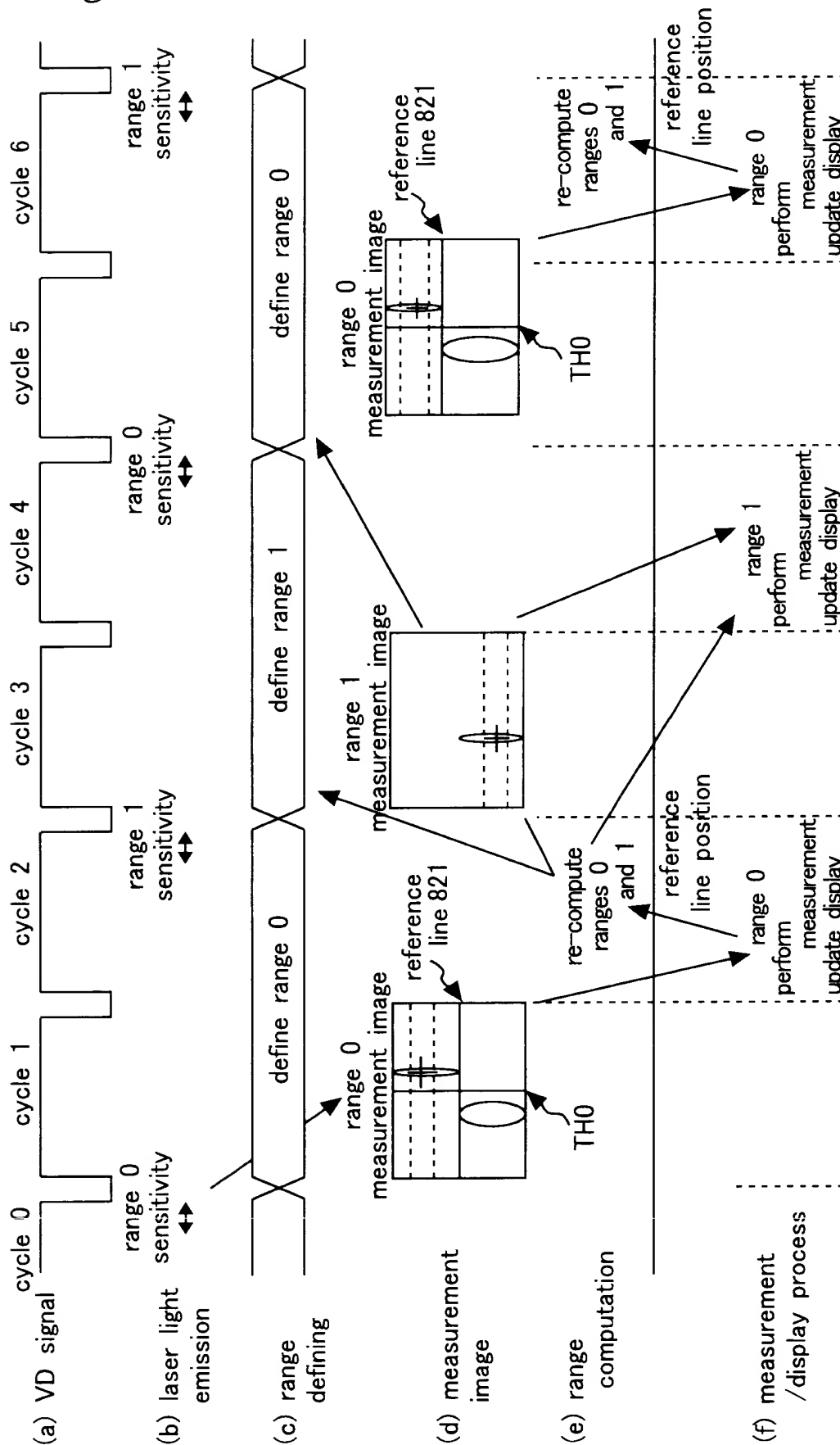


(when the measurement object is  
 at the reference position)

(when the measurement object has shifted laterally)

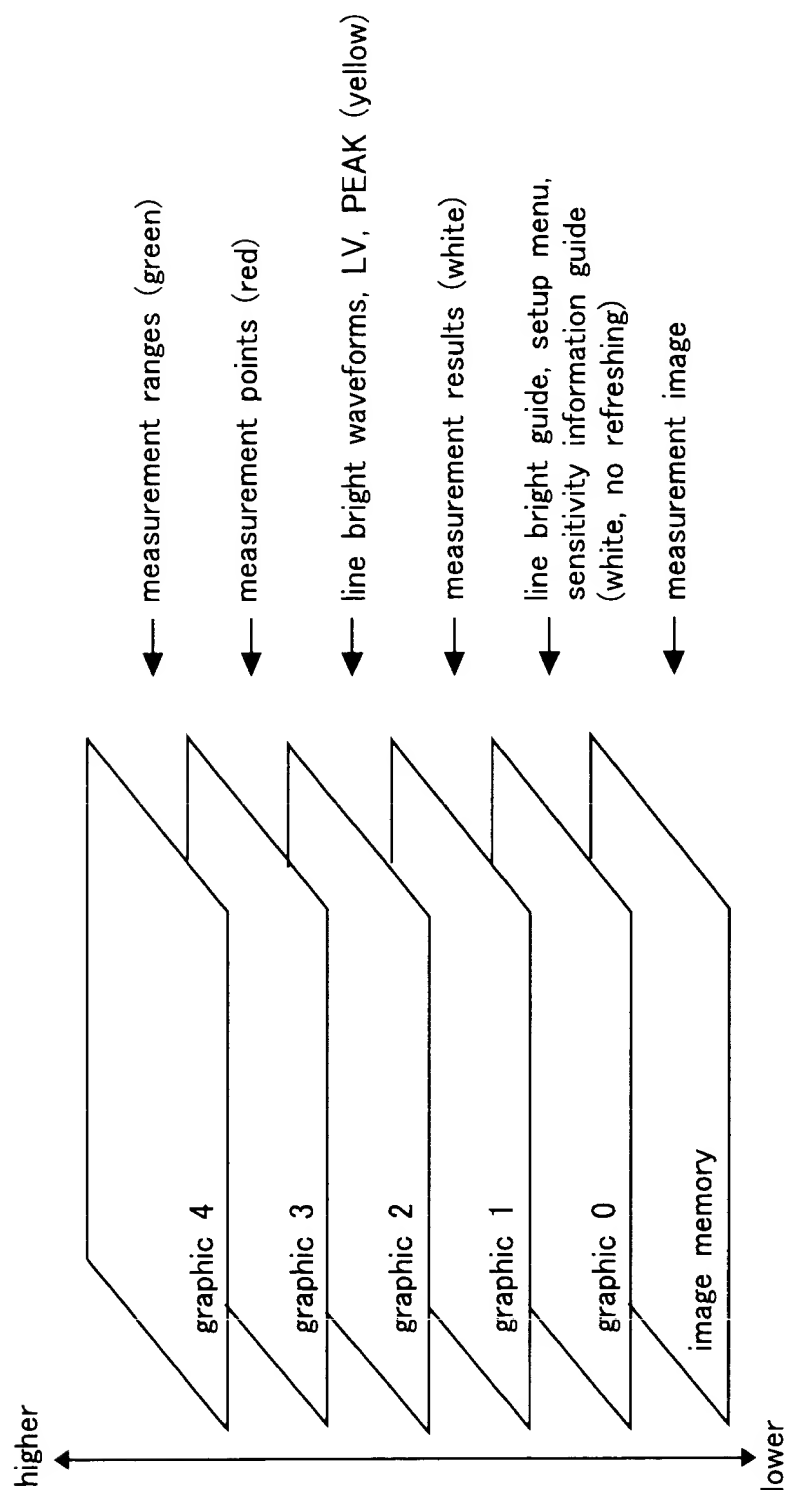
A view showing the control of tracking a lateral shift when measuring a step

Fig.31



A time chart showing the flow of the control process of tracking a lateral shift when measuring a step

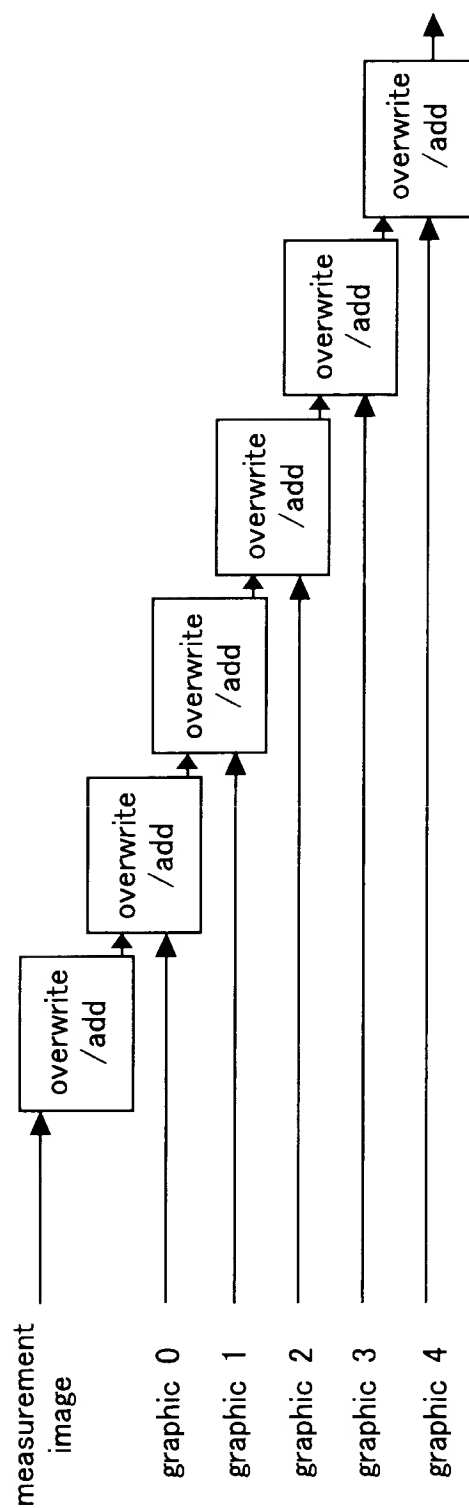
Fig.32



A view illustrating the process of composing a display for the image monitor (part 1)

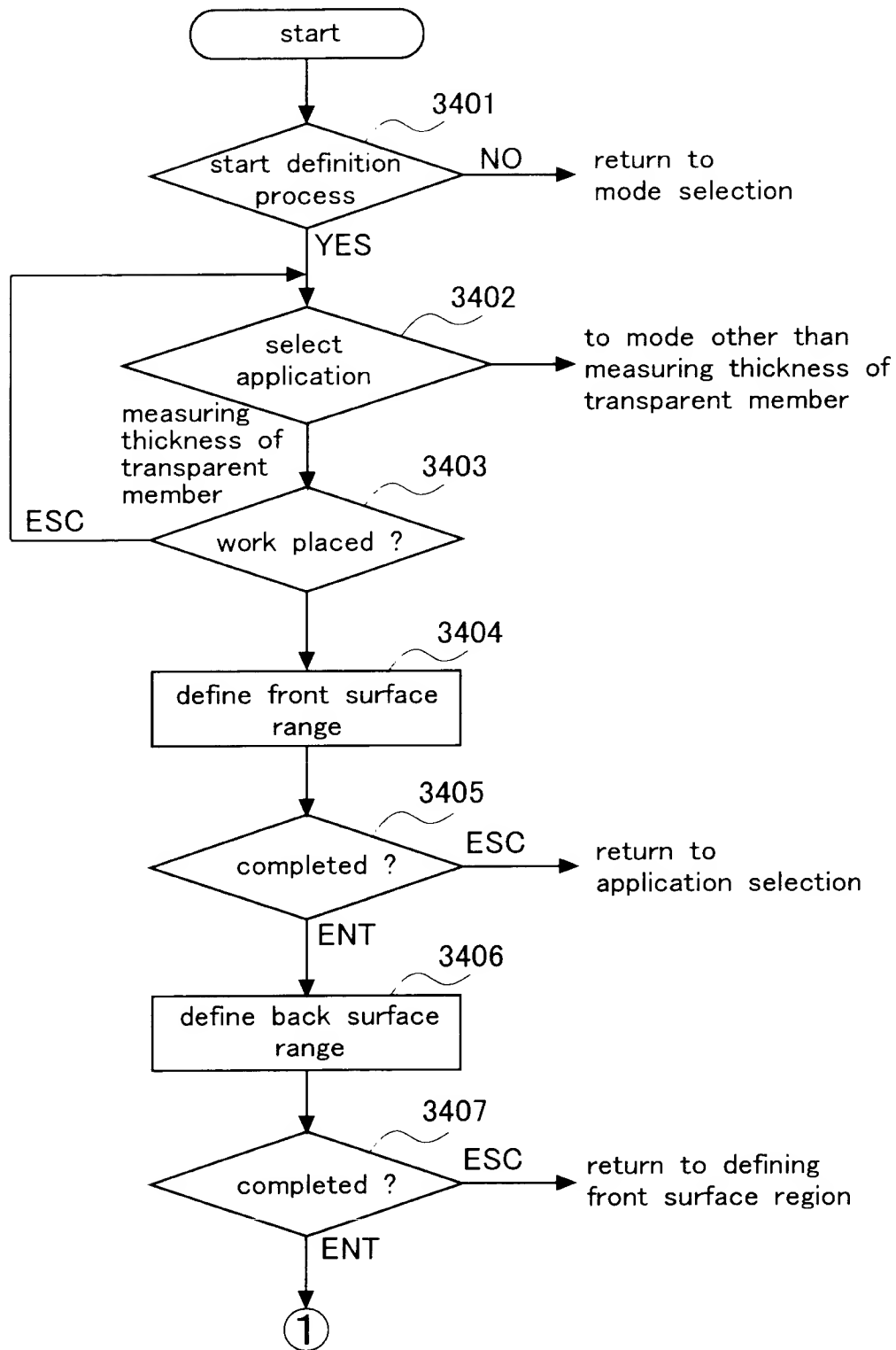


Fig.33



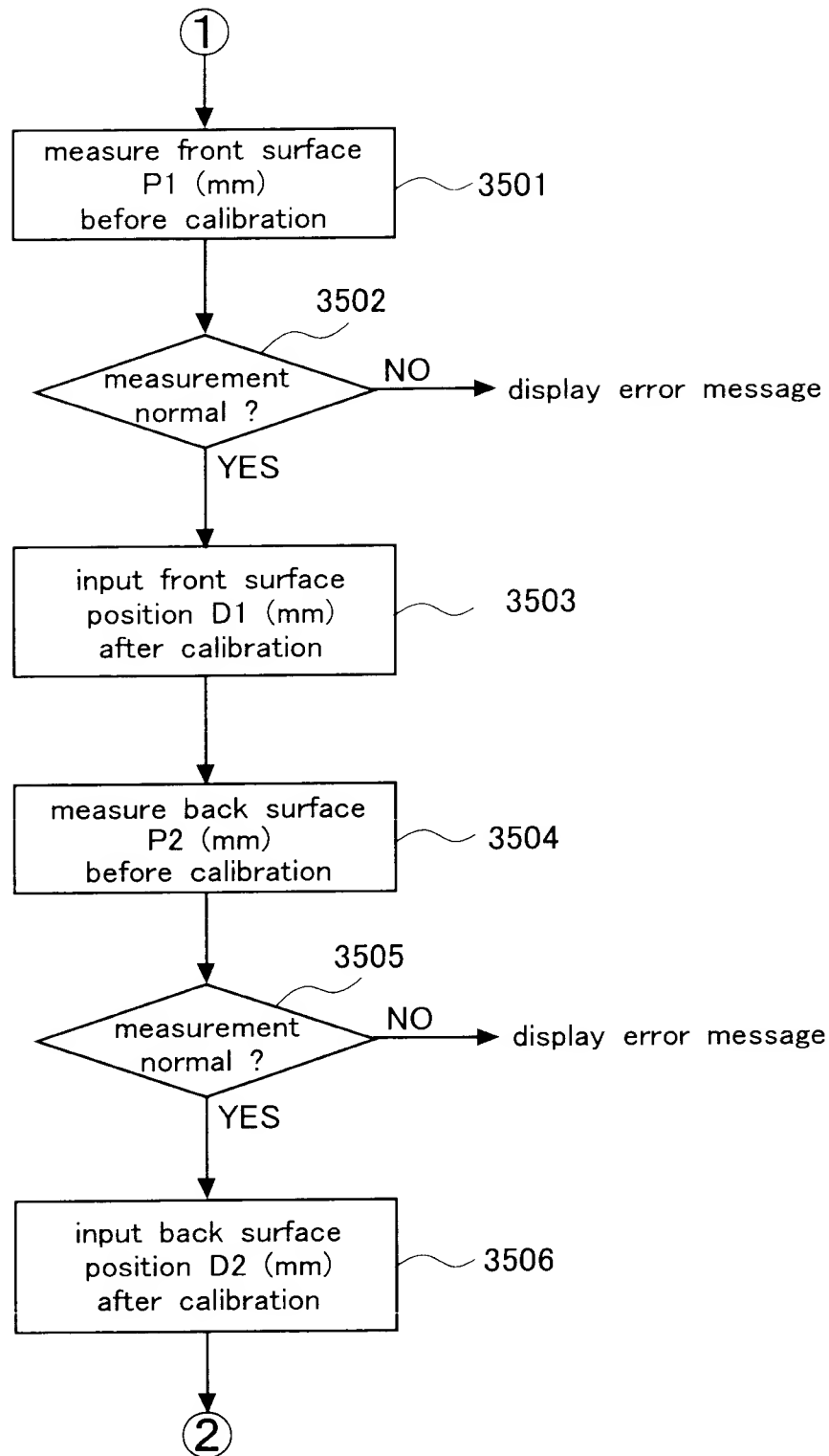
Aviiew illustrating the process of composing a display for the image monitor (part 2)

Fig.34



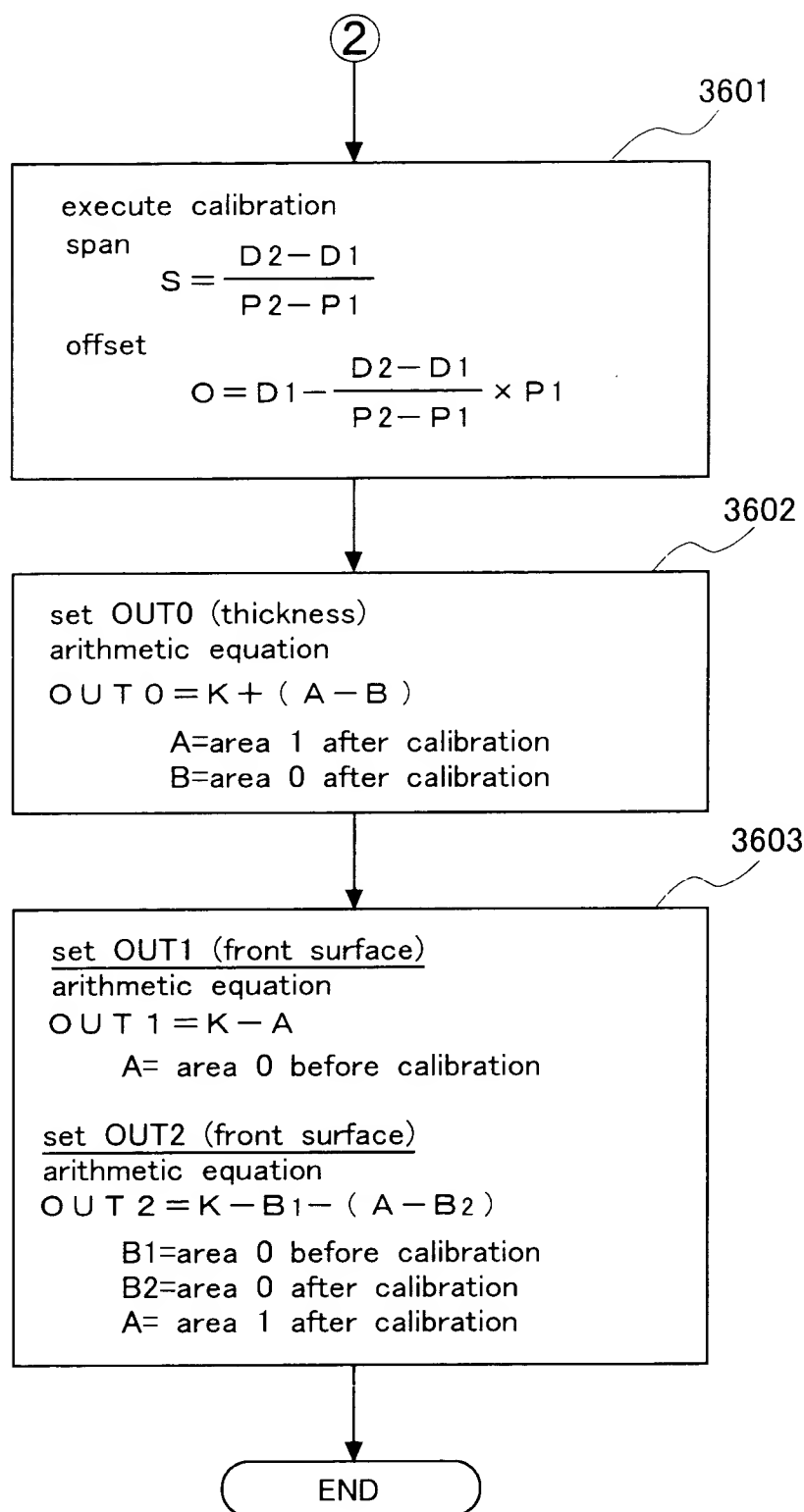
A flow chart showing the calibration process  
for the computation of the thickness of a transparent member (part 1)

Fig.35



A flow chart showing the calibration process  
for the computation of the thickness of a transparent member (part 2)

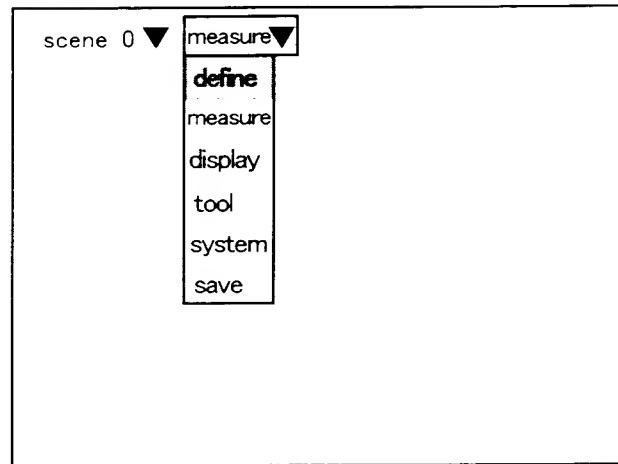
Fig.36



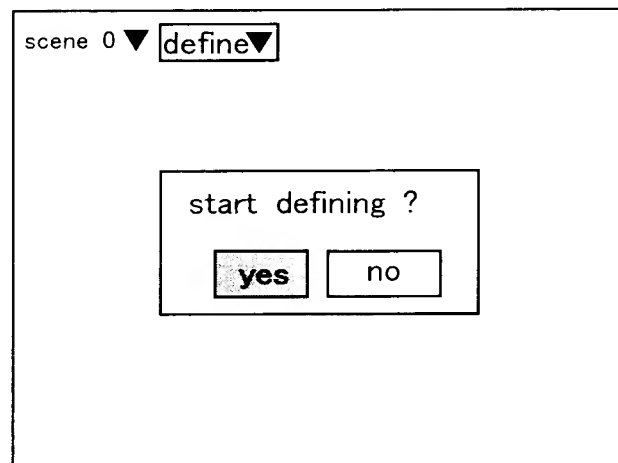
A flow chart showing the calibration process  
for the computation of the thickness of a transparent member (part 3)

Fig.37

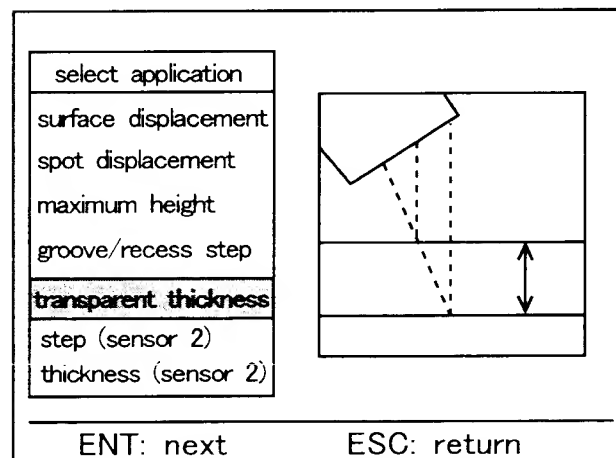
( a )



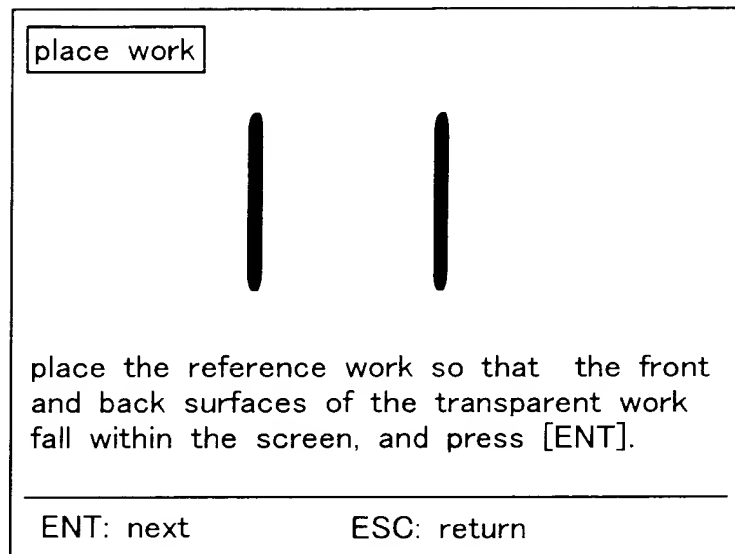
( b )



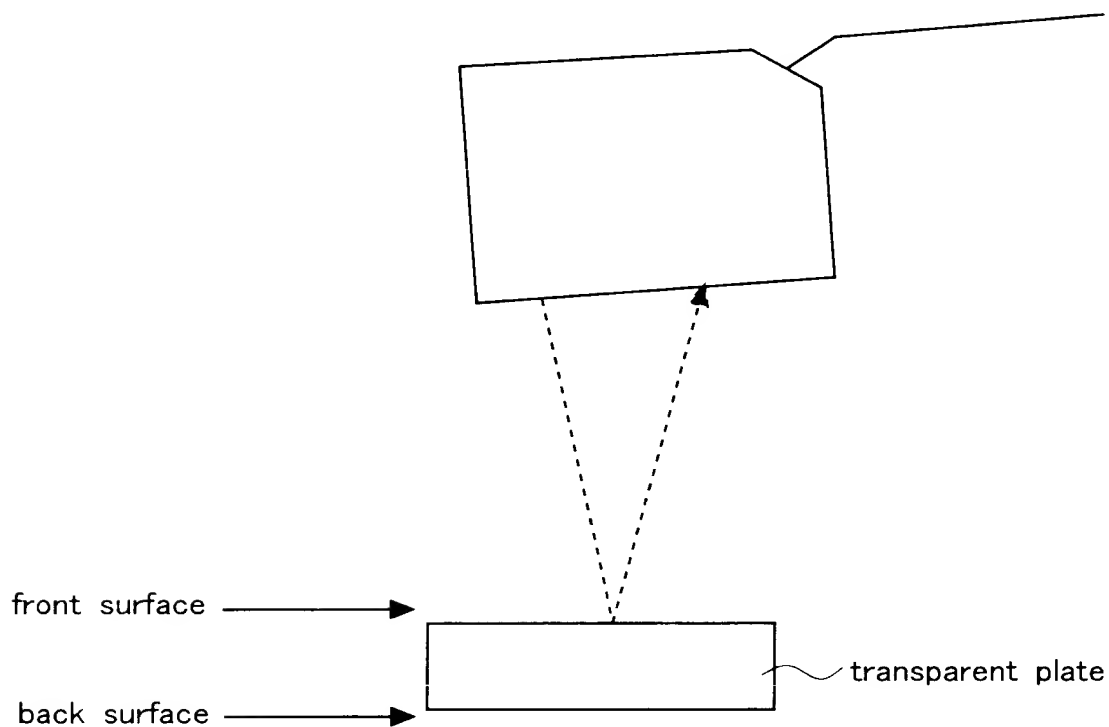
( c )



A view showing the monitor screen for the calibration operation  
for the computation of the thickness of a transparent member (part 1)



( a )

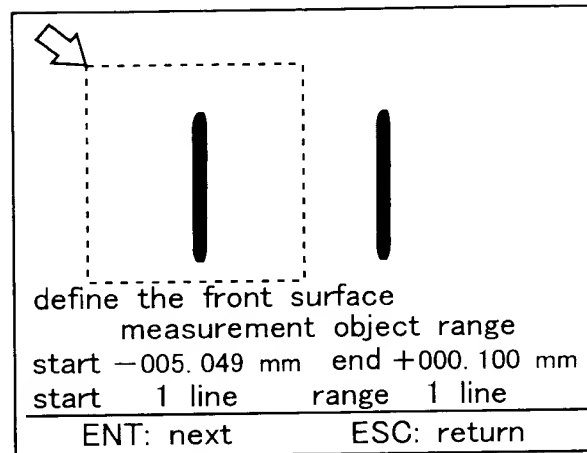


( b )

A view showing the monitor screen for the calibration operation  
for the computation of the thickness of a transparent member (part 2)

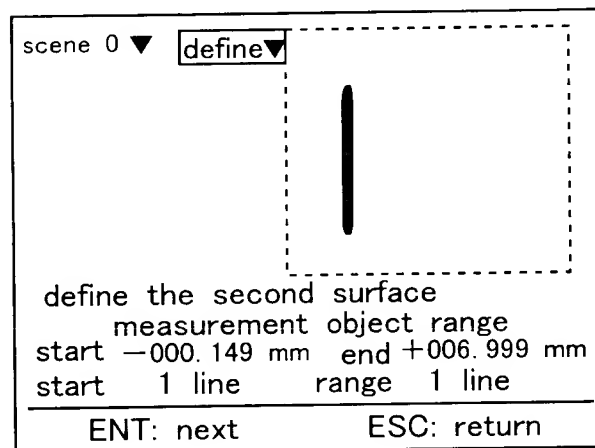
Fig.39

( a )



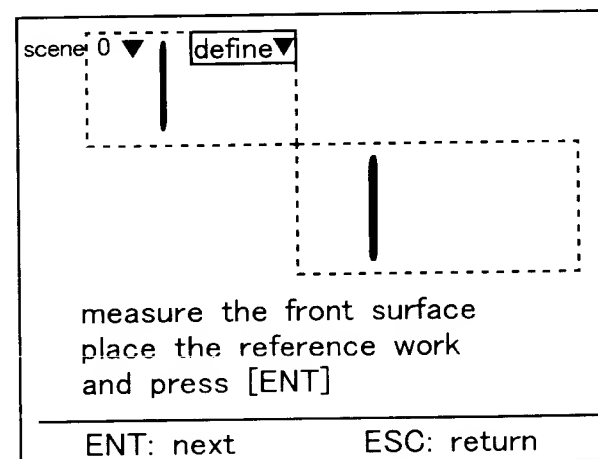
define the front surface  
measurement object range  
start -005.049 mm end +000.100 mm  
start 1 line range 1 line  
ENT: next ESC: return

( b )



scene 0 ▼ define ▼  
define the second surface  
measurement object range  
start -000.149 mm end +006.999 mm  
start 1 line range 1 line  
ENT: next ESC: return

( c )



scene 0 ▼ define ▼  
measure the front surface  
place the reference work  
and press [ENT]  
ENT: next ESC: return

A view showing the monitor screen for the calibration operation  
for the computation of the thickness of a transparent member (part 3)

Fig.40

( a )

scene 0 ▼ define ▼

0000.0000mm

enter the measurement value  
for point 1 and press [ENT]

---

ENT: next      ESC: return

( b )

scene 0 ▼ define ▼

measure the second surface  
place the reference work  
and press [ENT]

---

ENT: next      ESC: return

( c )

scene 0 ▼ define ▼

0001.0000mm

enter the distance  
between the two points

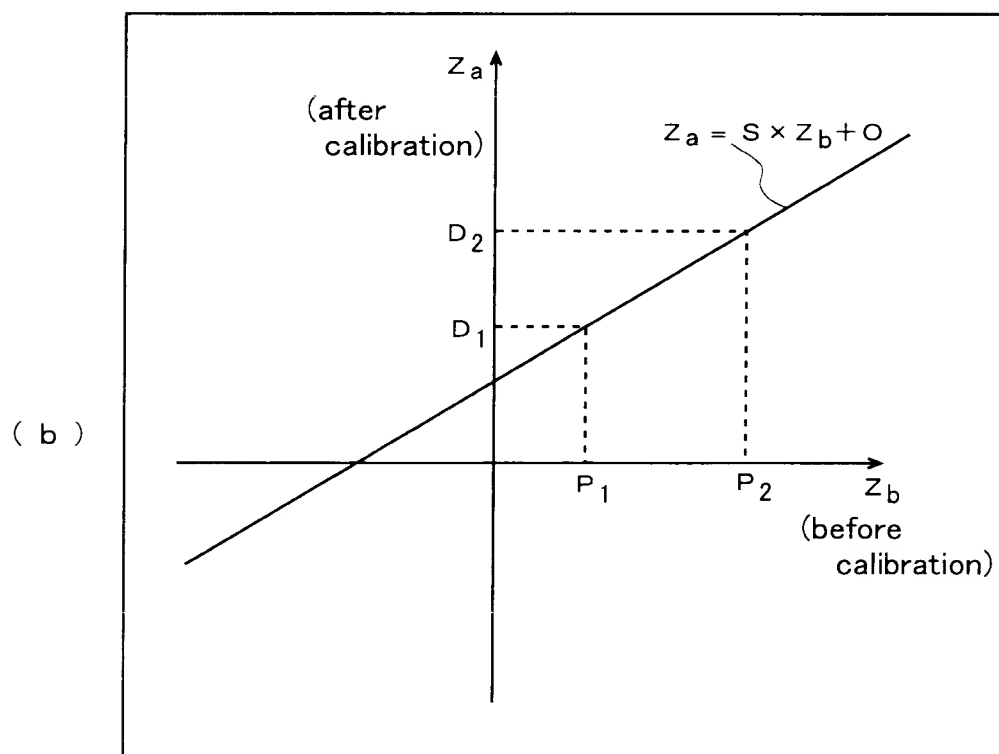
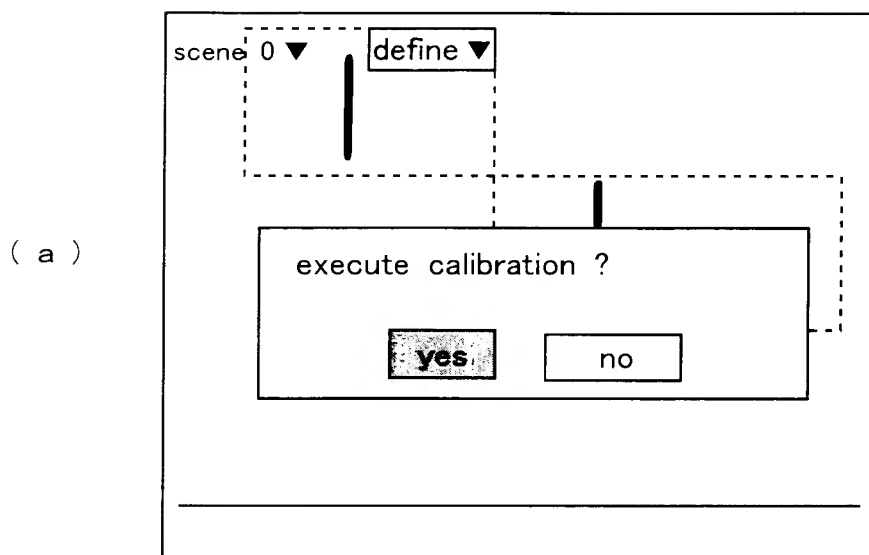
---

ENT: next      ESC: return

A view showing the monitor screen for the calibration operation  
for the computation of the thickness of a transparent member (part 4)



Fig.41



A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 5)

Fig.42

( a )

accept definition / register

application

transparent plate  
thickness

arithmetic  
equation

$K + ( A - B )$   
 $A = \text{area}$   
 $B = \text{area}$   
register in OUT0

register

cancel

return

( b )

measurement of each point  
can be allocated to the output  
front surface → OUT1  
back surface → OUT2

yes

no

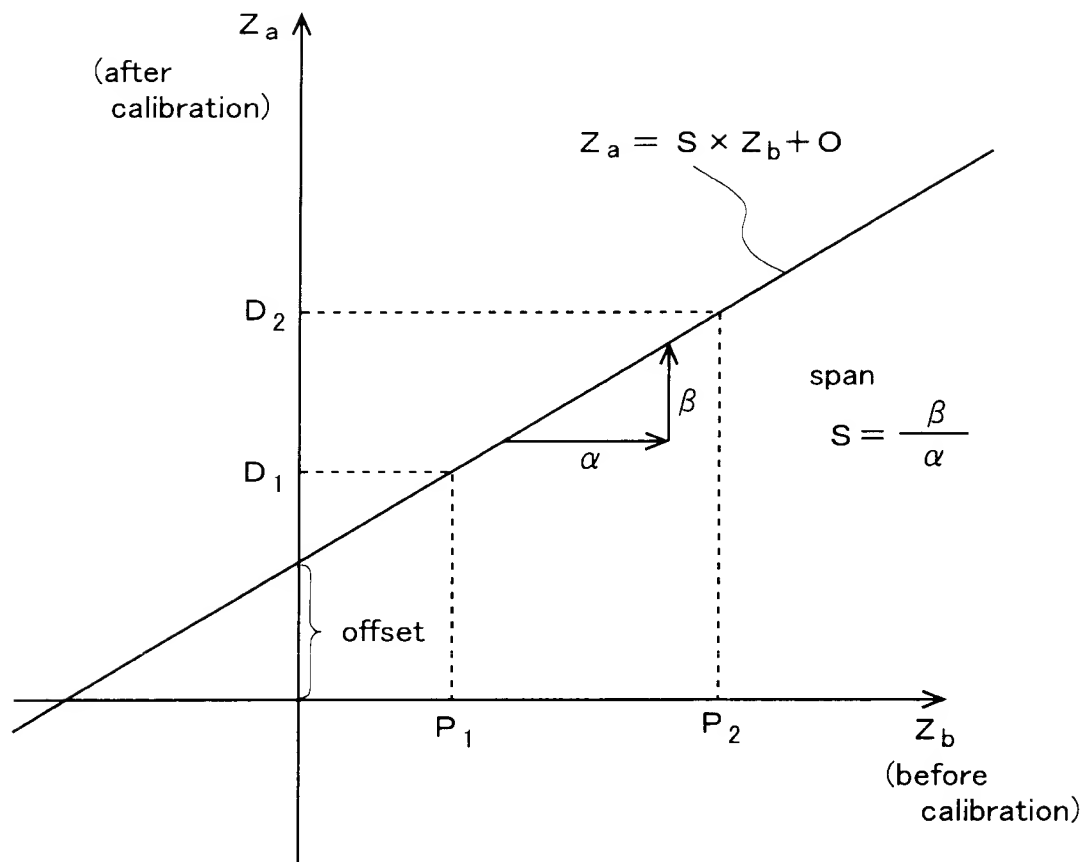
( c )

definition complete  
proceed to  
measurement mode

accept

A view showing the monitor screen for the calibration operation  
for the computation of the thickness of a transparent member (part 6)

Fig.43



$$S = \frac{D_2 - D_1}{P_2 - P_1}$$

$$O = D_1 - \frac{D_2 - D_1}{P_2 - P_1} \times P_1$$

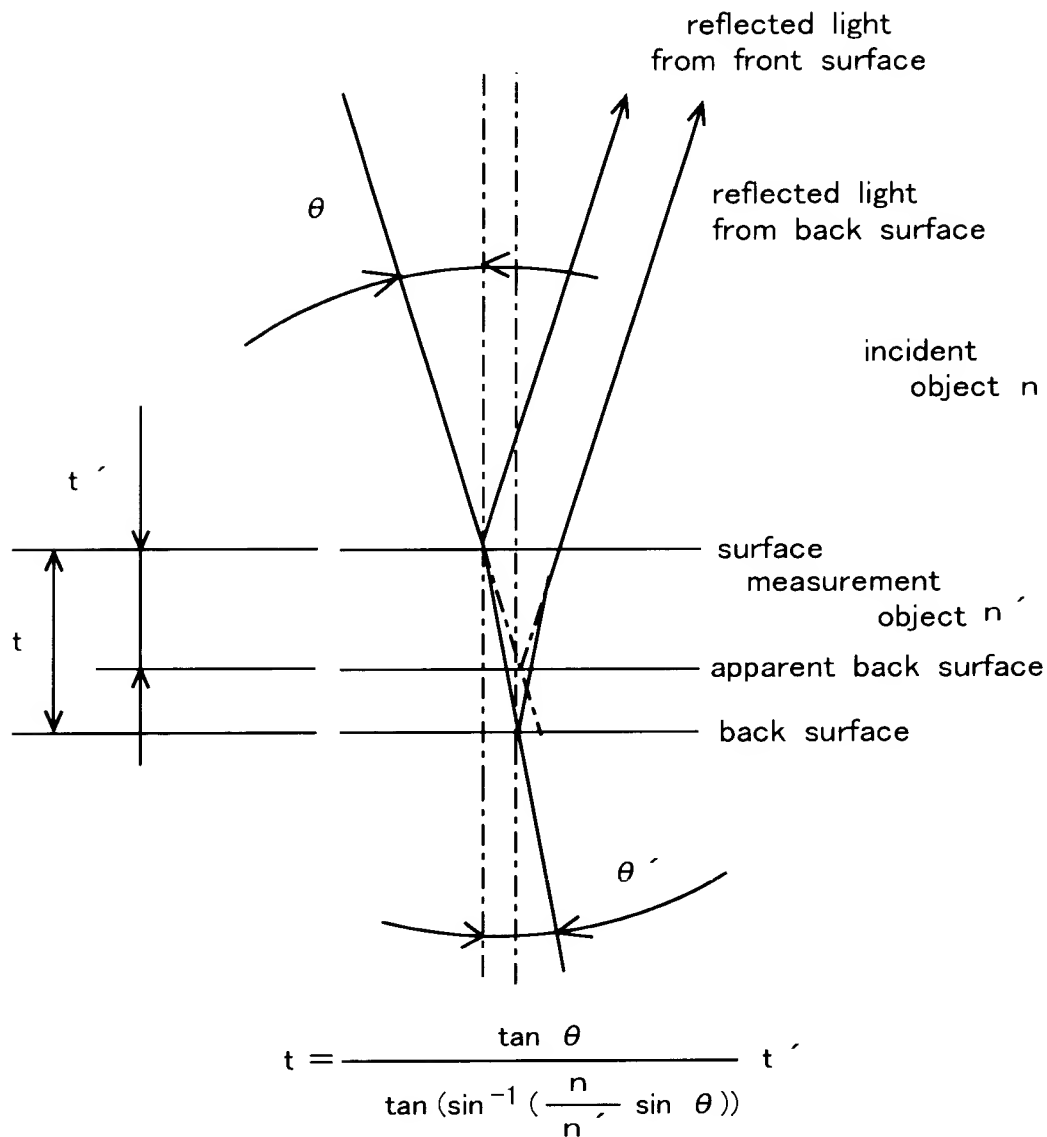
A view showing the algorithm for the calibration operation  
for the computation of the thickness of a transparent member

Title: VISUAL DISPLACEMENT  
SENSOR

Inventor(s): Tatsuya Matsunaga, et al.

DOCKET NO.: 058856-0106

Fig.44



$t$  : thickness of measurement object  
 $t'$  : sensor output value  
 $\theta$  : sensor light beam incident angle  
 $n$  : refractive index of incident object ( $n=1$  normally air)  
 $n'$  : refractive index of measurement object

refractive indices of typical transparent materials

air : 1.002	acrylic : 1.48~1.575
glass : 1.48~1.55	polycarbonate : 1.586
water : 1.333	

A view illustrating the reason for requiring a calibration for the measurement of the thickness of a transparent member by using the visual displacement sensor